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LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY

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M. L. Hyman

MARCH 1962

NUCLEAR DEFENSE LABORATORY

THE PFAUDLER CO.

A DIVISION OF PFAUDLER PERMUTIT INC. • ROCHESTER 3, NEW YORK

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LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY

A Final Engineering Report

by

W. F. Swanton
M. L. Hyman

Submitted to

NUCLEAR DEFENSE LABORATORY
U. S. Army Chemical Center, Maryland

Contract No. DA18-108-405-CML-1030
Order No. CP-1-405-13847

By

THE PFAUDLER CO.
a division of Pfaudler Permutit Inc.
Rochester 3, New York

Project G761-6006

FOREWORD

This final engineering report describes the design, development, and experimental evaluation of a semi-fixed liquid radioactive waste disposal facility. Recommendations for modification of the prototype design are included. The work was done by The Pfaudler Co., a division of Pfaudler Permutit Inc., for U. S. Army Chemical Corps Nuclear Defense Laboratory under contract No. DA18-108-405-CML-1030.

The project was administered for the Chemical Corps by Mr. Ernest W. Bloore, Contract Project Officer, and 2nd Lt. Allen Thieme. For The Pfaudler Co., Mr. W. F. Swanton was Project Engineer and the Project Supervisor was Mr. M. L. Hyman.

This report describes the work performed during the period 8 May 1961 to 25 January 1962.

ABSTRACT

A liquid radioactive waste disposal facility has been designed, developed, and installed at Nuclear Defense Laboratory for extensive tests and evaluation. The facility is being used for concentration of radioactive wastes from the Army nuclear power program and biological and medical research. It employs a Pfaudler Wiped Film Evaporator to effect gross decontamination of the waste and concentration of the waste by a factor of approximately 100. Condensate from the evaporator is further decontaminated by passage through Permutit mixed-bed demineralizers. The facility is a self-contained, transportable, semi-automatic assembly of monitoring, feed, and residue tanks, pumps, control panel, and ancillary equipment mounted on a skid. Results of preliminary evaluation tests using feed spiked with Co-60 to an activity $>8.7 \times 10^{-4} \mu c/ml$ in β indicate an overall DF of approximately 10^6 to 10^7. Initial test results did not determine ultimate facility capability because of errors in the vent piping, which have been corrected, and analytical limits imposed by background activity. DF for α appears to be about 10^3. Additional testing continues and will be reported by the Chemical Corps.

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1. INTRODUCTION

1.1 BACKGROUND

In the operation of nuclear reactors radioactive wastes are produced which must be handled and disposed of in a way so as to avoid gross contamination of the environment. Particularly troublesome to the reactor operator are the low-level, low-purity aqueous wastes that are generated from equipment decontamination and laundering operations, and which result from laboratory activities. High-purity wastes are readily decontaminated by passage through disposable mixed-bed demineralizers, permitting discharge of effluent of acceptable purity to a natural water course. Treatment of the low-purity wastes by ion exchange is generally uneconomical, and often not possible, because of the presence of relatively large amounts of ionized, stable species which compete with the radionuclides for active sites on the resin. The resin is quickly exhausted and, once contaminated, it represents a disposal problem of its own.

A more flexible treatment scheme for low-level, low-purity wastes employs evaporation to reduce the highly dilute active solutions to a conveniently handled concentrate, now a small fraction of the original waste. The bulk of the original waste volume is a relatively pure effluent which, after subsequent treatment by demineralization, can be released safely to the environment. The principal advantage of an evaporation system is its ability to handle all kinds and concentrations of waste while evaporation capacity and operating costs remain essentially independent of the waste composition.

1.2 OBJECTIVE OF THIS PROJECT

The objective of this project was to design, assemble, and test a semi-fixed liquid waste disposal facility, to be installed at the Nuclear Defense Laboratory, which will accomplish the concentration and disposal of certain wastes now at the Army Chemical Center. In addition, the system was to be sufficiently flexible so that it can eventually be used by Chemical Corps personnel for routine disposal of diverse radioactive wastes which must be processed and disposed of in compliance with the mission requirements set forth by higher command. The facility was designed and constructed under a research and development contract in accordance with specified design and performance requirements.

1.3 DESIGN AND PERFORMANCE REQUIREMENTS

1.3.1 General

This facility is capable of treating a variety of low-level radioactive liquid wastes, such as those produced by the Army Nuclear Power Program, from the laundering of contaminated clothing, and from biological and medical research laboratories. An analysis of certain of these wastes indicates a total solids content (not entirely dissolved) of 450 to 4000 ppm, an activity level of $10^{-\text{[illegible]}}$ to $10^{-\text{[illegible]}}$ $\mu c/ml$, and a pH of 4.5 to 7.0. Semi-fixed design allows removal of the facility to another site where wastes must be processed.

Treatment consists of:

a. Concentration of the activity by evaporation to maximum solids content that will still allow the concentrated waste to flow freely through the residue line to a drum which will contain the waste.

b. Decontamination of the distillate by entrainment separation and demineralization to a specified acceptable activity level.

1.3.2 Semi-fixed Design

The equipment is capable of being positioned by two 4-ton fork lift trucks and of being installed on a prepared site or disconnected for removal within 8 hr, and of being transportable by aircraft. Its overall dimensions are 14 ft x 10 ft x 10 ft 7 in. high. It weighs approximately 7000 lb.

1.3.3 Decontamination

The maximum permissible concentration for unidentified nuclides discharged to unrestricted areas is $10^{-8} \mu c/ml$. Primary coolant water, which may be a source of contaminated liquid waste, is approximately $10^{-1} \mu c/ml$. Therefore, the facility must be capable of a DF of 10^{7} for a feed activity of $10^{-1} \mu c/ml$. It is not required that this be achieved in a single pass. Recycling is permitted to accomplish the required decontamination.

1.3.4 Capacity

A capacity of at least 150 gal per 8 hr shift is required. This includes start up time, operation time, sludge removal, and shut down time.

1.3.5 Sludge Removal

Sludge is to be transferred to 55-gallon drums for ultimate disposal by the Government.

2. TECHNICAL APPROACH

2.1 DESIGN OBJECTIVES

Stored radioactive liquid waste represents a hazard. The objective is to accomplish "ultimate disposal" of the waste to eliminate the existing hazard and solve the storage and monitoring problems. Reduced to its practical aspects, the objectives in designing a disposal facility are as follows:

1. Process the dilute liquid waste by evaporation to a small volume of concentrated waste.
2. Decontaminate the pure water distilled in the evaporation process to a level of radioactivity which, under Federal and State regulations, will allow its direct disposal to a sanitary sewer or natural water course for further dilution and dispersion to the environment. A level of activity always acceptable to the AEC is $10^{-8} \mu c/ml$, the maximum permissible concentration for unidentified nuclides discharged to an unrestricted area. Higher activities are permissible if certain radionuclides are not present. (See Section 20.106 of Title 10, Code of Federal Regulations, Part 20.)
3. Provide a means for containing the concentrated radioactive waste in a form whose integrity cannot be readily breached. This may be a drum of concrete made up of the waste slurry and cement. Alternatively, the waste may be thickened with a bulking agent, such as vermiculite, and allowed to harden in the drum. The entire drum may finally be disposed of by burial at sea or at a national burial ground, all in accordance with AEC regulations.

Additional aqueous wastes are routinely received by the Chemical Corps and these too must be disposed of. The treatment process therefore had to be a generalized scheme suitable for all low-level, low-purity wastes.

2.2 DESIGN PHILOSOPHY

A compact, versatile evaporation system was designed as the solution to the low-level waste concentration problem. Criteria that have guided the design and which are incorporated in the system are as follows:

1. Overall decontamination factor of 10^7 as a minimum.
2. Capable of handling foaming wastes of varying composition.
3. Capable of producing a flowable residue of maximum solids concentration, expected to be in the range 50 to 80% solids.
4. Compact, semi-portable assembly.
5. Positive self-cleaning (non-scaling) evaporator design.
6. Reliable operation with minimum operator attention.

7. Stainless steel construction to avoid corrosion and to allow the system to be decontaminated with nitric acid in the event direct maintenance becomes necessary.

8. Practically leak-proof design but consistent with the use of standard commercial equipment.

9. Adequate system capacity for disposal of wastes as generated at the plant by operating the system regularly but not continuously.

The design philosophy of the system is the employment of evaporation to effect gross decontamination of the bulk of the water in the waste, producing a concentrated residue ready for drumming and disposal. To provide the maximum decontamination of the distillate from the evaporator, the water is passed through a mixed-bed demineralizer. If necessary, two demineralizers can be used in series. Since it will be distilled water which is passed through the ion exchange units, their exchange capacity for the radioactive species will not be reduced by foreign, nonradioactive ions. This is the most economical use of ion exchange units possible.

2.3 EQUIPMENT SELECTION

The system employs process equipment units which have previously been designed for commercial installations and which are at a high level of development. The evaporator is a Pfaudler Wiped Film Evaporator, which was modified to increase the decontamination factor achieved in the unit. The evaporator was modified by installing a special wire mesh as a second internal entrainment separator, and by making the condenser a separate external unit. Additional deentrainment is achieved by passing the vapor from the evaporator through a packing of wire mesh at a relatively low velocity, which is contained in a separator vessel. The primary advantage of the Pfaudler evaporator design is the positive wiping contact made by the wipers freely mounted on the rotor; this provides the positive scraping and self-cleaning operation inherent in the machine.

The demineralizers are Permutit Model XP-15 Nuclear Purifiers, low-cost disposable ion exchangers specially designed for waste treatment. These units are widely used wherever slightly contaminated, high-purity water must be treated. A newly developed unique feature that was employed in the demineralization step is the provision of a disposable ion exchange unit charged with a special Ionac resin which is specific for cobalt ions. This anion resin complexes cobalt-60 and has a greater affinity for that radionuclide than the cation resin present in the mixed-bed demineralizer.

The balance of the system employs standard components suitable for use with low-level radioactive solutions. "Nuclear grade" equipment was not selected because of the excessive cost of such apparatus and the lack of a clear need for extremely high standards of reliability and integrity. The activity to be encountered by the equipment, if not confined, can be troublesome, but the level is not such as to present a serious radiation danger.

2.4 PRIOR SUPPORTING EXPERIMENTAL WORK

In an attempt to determine experimentally the decontamination factors to be obtained in a Wiped Film Evaporator, an experimental program was carried through at the Pfaudler Engineering Test Center prior to the start of this project. The tests employed a 4 sq ft, 12-in. diameter Wiped Film Evaporator equipped with an internal condenser and operated at atmospheric pressure. Feed solution was approximately 10% NaOH; one series of runs contained 1.5 wt.% Tide as well. Distillate and residue were analyzed for sodium ion to determine decontamination and concentration factors, respectively.

Several parameters were investigated briefly, including feed rate, steam temperature, and type of entrainment separator. Decontamination factor was found to vary inversely with feed rate and steam temperature. The range of DF obtained in the runs was 10^4 to 10^5, a reasonable value for the particular equipment employed being 5×10^4. It was found that the system DF was not affected by the presence of Tide in the feed, which indicated that foaming would not be a problem in the Wiped Film Evaporator.

Concentration ratio, which is the ratio of solids in the residue to that in the feed, was found to vary with feed rate, as is to be expected. A concentration ratio of 3 to 5 can readily be obtained in the 4 sq ft unit; it is higher in a larger evaporator.

This experimental work, while limited in scope, provided sufficient data to indicate the probable operating conditions for a Wiped Film Evaporator in the waste concentration service. The DF to be expected in the Wiped Film Evaporator was expected to be greater than that achieved in the early experimental work on account of the proposed modifications.

Much experimental work had already been done at The Permutit Company and elsewhere on the treatment of low-level aqueous waste with mixed-bed ion exchangers. The data have previously been analyzed.* A conservative design value for DF of 10^3 has been suggested for treating a waste of activity level in the range 10^{-4} to 10^{-6} μc/ml and at a flow rate of 2 gpm/cu ft of resin. The resin bed is generally a mixture of 1 part cation to approximately 2 parts anion resin by volume. Additional decontamination of cobalt would be achieved with the special complexing anion resin mentioned above.

2.5 OVERALL DECONTAMINATION FACTOR FOR SYSTEM

The minimum overall DF for the system must be 10^7 if a waste of 10^{-1} μc/ml is to be reduced to 10^{-8} μc/ml activity. A higher DF is certainly to be desired so as to accommodate more active wastes and to reduce the radioactivity of the effluent to a value even less than the acceptable MPCU.

To the unwary it would seem to be easy to achieve high DF; just treat the waste in a series of apparatus, and add the separate DFs to obtain a high overall DF. For example, it might be thought that waste that has been decontaminated by a factor of 10^6 in an evaporator can then be treated in a demineralizer, whose DF is usually 10^3, to get an overall DF of 10^9. That this is not always possible is due to the following reasons:

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*Hyman, M. L., W. F. Swanton, et al., "Disposal of Radioactive Wastes from Nuclear Reactors in the Arctic," Pfaudler Permutit Inc., RADC-TR-60-114 (AD-240060), April 1960.

1. The DF for any equipment generally decreases with feed activity. That is, it is more difficult to decontaminate very low activity influents.

2. Certain radionuclides may form volatile compounds which appear in the distillate from an evaporator, while others are inert to an ion exchange resin. (An advantage to a process employing evaporation and ion exchange in series is that the one may overcome the deficiencies of the other.)

3. It becomes increasingly difficult to determine the very low levels of activity in a highly decontaminated effluent. Analytical techniques are strained to measure activities approximating normal background levels, and the degree of uncertainty in the reported values is great.

With the limitations described above kept in mind, it was still possible to predict a probable overall DF for the proposed system. The design data for the system are given below.

Component	Probable Minimum DF	Activity, μc/ml	
		Inlet	Outlet
Evaporator	10^5	10^{-1}	10^{-6}
Demister	5	10^{-6}	5×10^{-7}
Demineralizer	10^3	5×10^{-7}	$<10^{-8}$

2.6 ANALYSIS OF EVAPORATOR OPERATION

It is of interest to combine certain assumptions regarding the feed and residue properties with known capacities of the Wiped Film Evaporator and analyze the typical anticipated operation of the system.

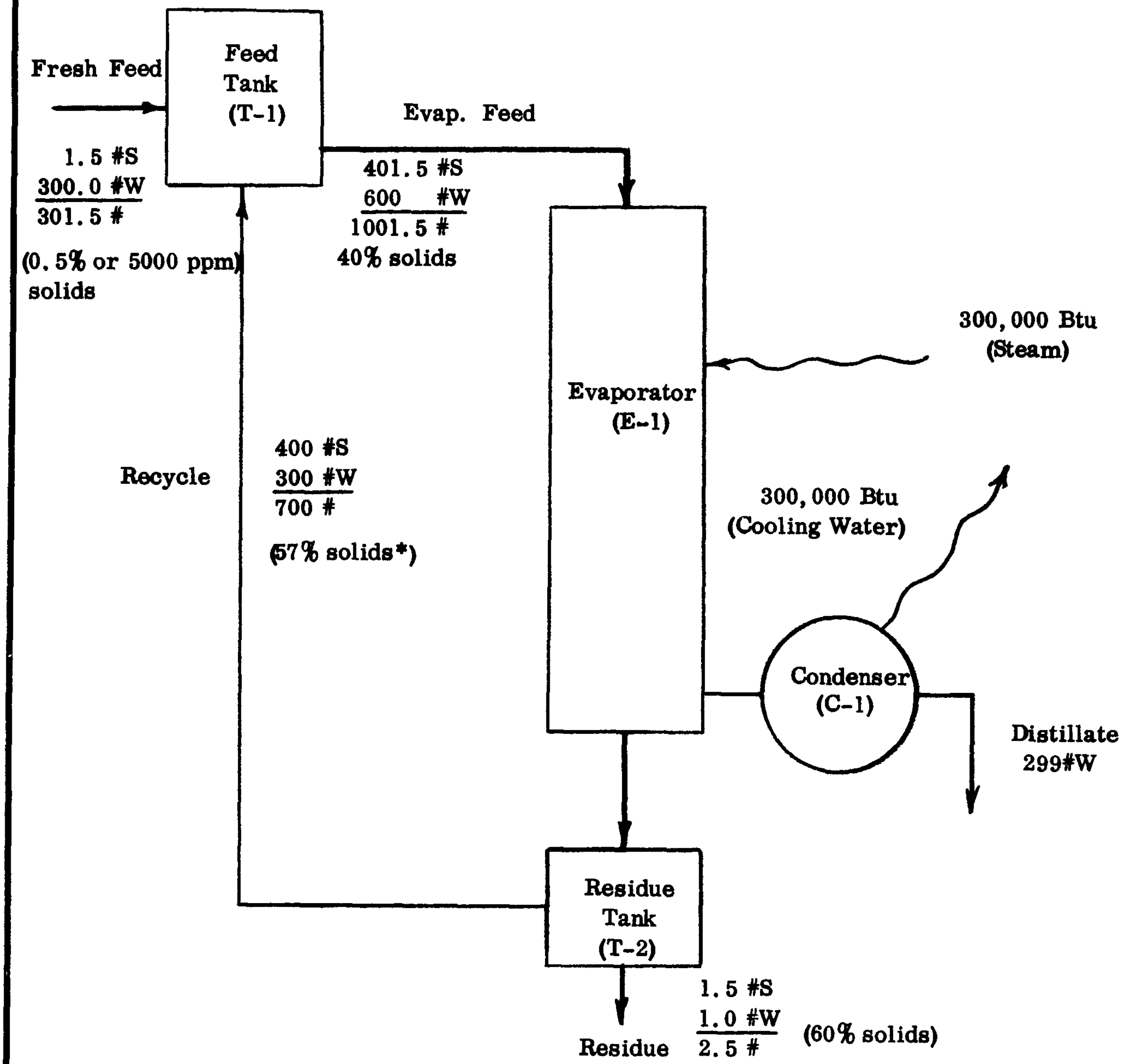
From previous experience and the prior experimental work, one may assume a minimum evaporation capacity of 25 lb/hr sq ft evaporator surface, or 300 lb/hr for the 12 sq ft unit. At this evaporation rate, a concentration ratio of four is easily achieved. It may further be assumed that the untreated radioactive waste contains only 0.5% solids and that it is desired to concentrate the waste to a residue containing 60% solids. Since a single pass through the evaporator is insufficient to produce the desired 60% concentration, recycle of the residue is necessary until the proper concentration is reached. Thereafter some of the residue is recycled with the fresh feed. The recycle stream will be roughly twice the fresh feed, depending on process conditions. The assumed and calculated data are summarized below.

Assumed	
Feed concentration	0.5% solids
Residue concentration	60.0% solids
Concentration ratio per pass	4
Evaporation rate	300 lb/hr

Calculated	
Fresh feed rate	301.5 lb/hr (36 gal/hr)
Distillate rate	299 lb/hr
Residue rate	2.5 lb/hr
Recycle rate	700 lb/hr
Overall concentration factor	120

Figure 1 is a material and heat balance on the evaporator. It schematically illustrates idealized operation of the evaporator system. It shows, for example, that all solids entering the system leave with the residue and that practically all of the water leaves as decontaminated distillate. Of most significance is the fact that it will be possible to reduce the dilute radioactive waste to about 1/120 of its original volume, or even to a smaller volume if the original feed contains less solids than was assumed.

It is common practice to mix the residue from a radioactive waste evaporator with cement and to allow the mixture to set up in a 55-gallon drum. The resulting solid concrete block is safe to handle and may be disposed of at sea or by burial. A low-strength concrete may be made from a mixture containing, in parts by weight, 80 water, 100 cement, and 500 aggregate. It will be apparent that even allowing for a pre-formed concrete shield inside the 55-gallon drum and for additional aggregate and sand in the concrete mix, the volume of the concentrated (60%) residue from the evaporator should not be more than half the capacity of the original drum. The final volume of the contained waste to be disposed of will, on this basis, be about 1/60(less than 2%) of the original liquid waste.



Basis: 1 hour operation

S = solids
W = water

*Solids in recycle are less than in residue tank because recycle is drawn from side rather than bottom.

THE PFAUDLER CO.
PROJECT ENGINEERING
FIGURE 1
MATERIAL AND HEAT BALANCE DIAGRAM

FOR NUCLEAR DEFENSE LABORATORY
PROJECT G761-6006 MLH DATE 2/27/62
BY WFS CHKD. REV.
DWG. NO. SH. 1 OF 1

3. DESCRIPTION OF FACILITY

3.1 GENERAL

The facility is an assembly of equipment mounted on a permanent steel frame to allow it to be moved readily to any site. It is complete in itself, requiring only process and utility connections for it to be operable as a treatment system. Figures 2 and 3 are photographs of the facility taken prior to installation. Figure 4 shows the layout of the equipment constituting the facility. The flow diagram for the processing of the liquid waste is shown in Figure 5.

The facility includes a feed pump, P-1, for effecting the transfer of stored wastes from existing storage tanks to a feed tank, T-1, in which recycled residue or concentrate is mixed with dilute fresh feed. The mixture flows by gravity from T-1 to a Pfaudler Wiped Film Evaporator, E-1, where condensing steam vaporizes part of the feed. Unvaporized residue drains into the residue tank, T-2, from which it is pumped to T-1 or to a sludge receiving drum. The vapors pass through two entrainment separators in the evaporator and an external separator, S-1, to a condenser, C-1. Condensed vapors or distillate drains into either of two receivers, T-3A or T-3B. From tank A (or B) the distillate is pumped through either or both of two mixed bed demineralizers, IX-1 and IX-2, to either of two final monitoring tanks, demineralized water tanks, T-4A or T-4B. After this final check point the distilled or demineralized water is pumped to waste.

The equipment in the facility is designed to be vapor tight, but is expected to be operated under a vacuum of a few inches of water to prevent any out-leakage. The vacuum will be produced by a fan or blower (by the Government) to which the vent line is connected.

Sample or drain points are provided so that activity checks may be made on solution at any point in the facility and so that it may be completely drained.

Provision is also made to recycle solution through any component, even back to the main storage tanks, but no provision has been made for by-passing the evaporator.

3.2 DETAILED DESCRIPTION

3.2.1 General

Specifications for all the items of equipment constituting the facility will be found in the Appendix. The essential features of the major equipment are summarized in the following sections.

3.2.2 Evaporator, E-1

The Pfaudler Wiped Film Evaporator is essentially a vertical cylinder containing an internal rotor. The standard design is shown in Figure 6. The rotor includes four vertical columns of wipers which wipe the entire inner surface of the cylinder as the rotor

FIGURE 2. SEMI-FIXED LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY. RIGHT-FRONT VIEW. (3033A)

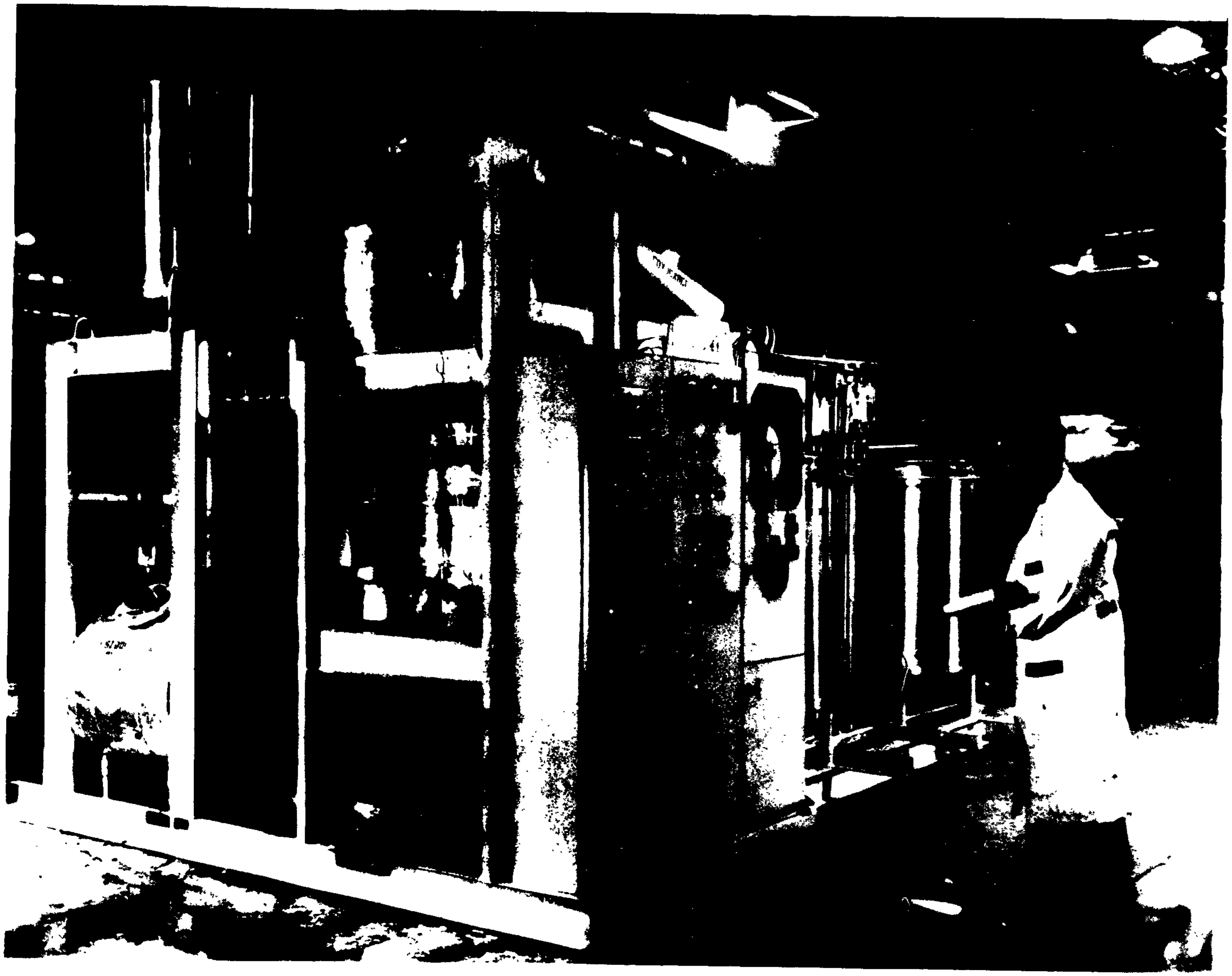


FIGURE 3. SEMI-FIXED LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY. LEFT-FRONT VIEW. (3033B)

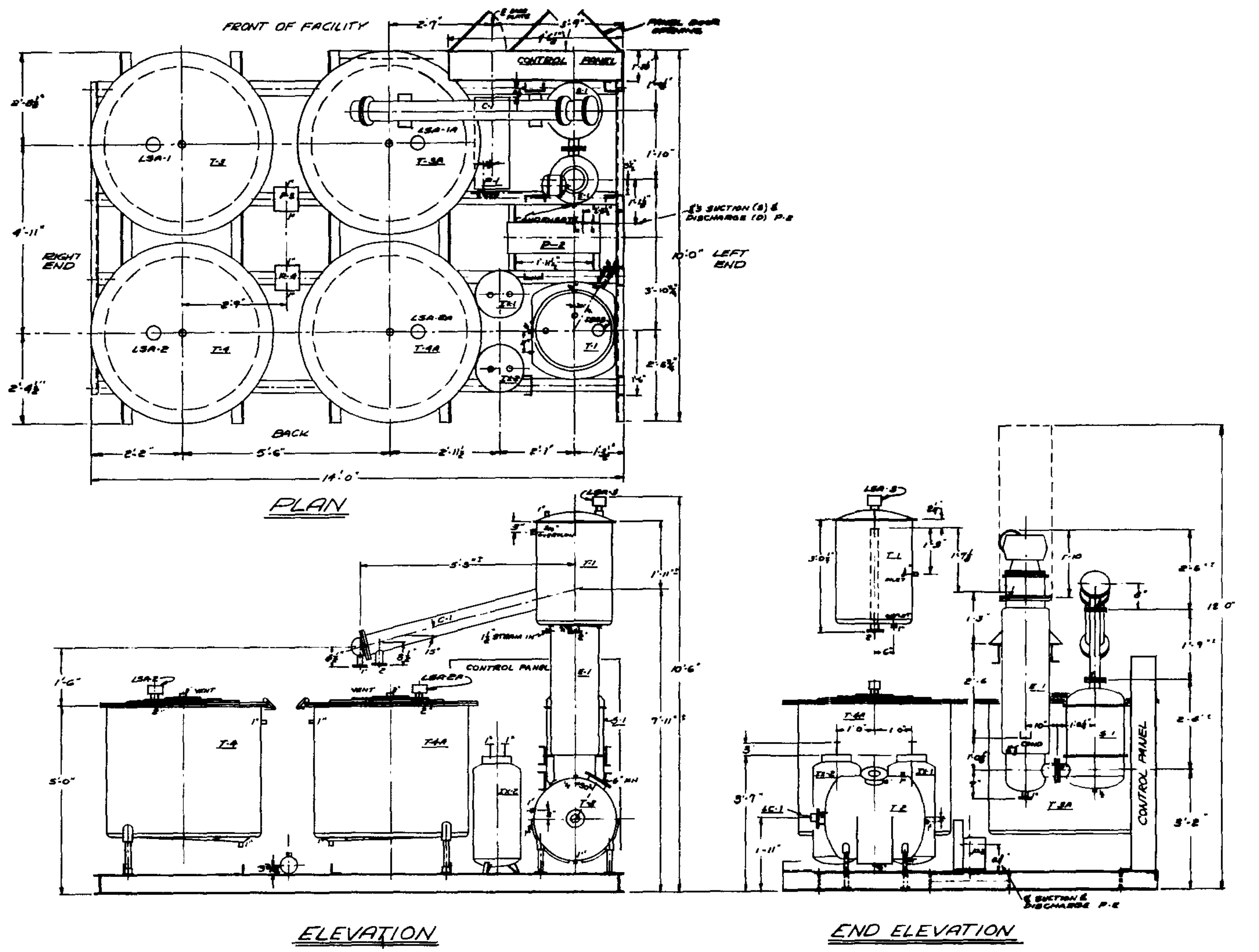


FIGURE 4. EQUIPMENT LAYOUT OF SEMI-FIXED LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY. (JC-1200-20-3)

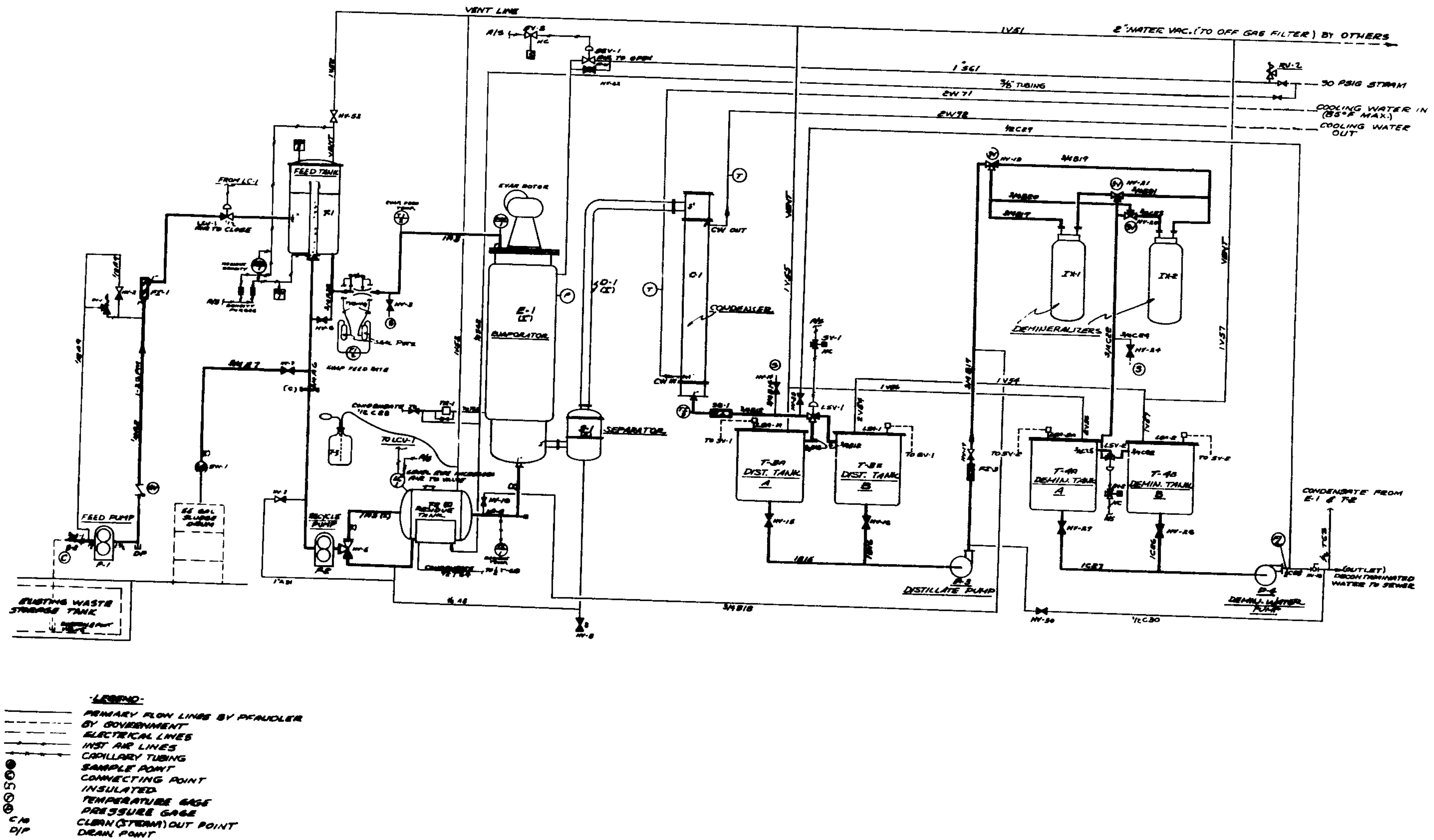


FIGURE 5. FLOW DIAGRAM OF SEMI-FIXED LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY. (JC-1200-1-9)

turns. All internal parts, except the wipers, are of stainless steel. Liquid feed entering at the top is distributed through four spouts just ahead of the wipers to the inner surface. The liquid is wiped into a thin film (and given a downward push) by the wipers so that heat from steam condensing within the jacket vaporizes part of the feed without bubble formation. This nonboiling vaporization accounts for the very low entrainment from the evaporator. The rotor not only carries the wiper assemblies but also the first entrainment separator which forces the vapor to change direction twice before it reaches the central space in the evaporator.

The evaporator that was installed in the waste disposal facility was modified from the standard design shown in Figure 6. These modifications, shown in Fugure 7, were (1) installation of a low, compact right-angle gear drive, (2) removal of the internal condenser, allowing the residue drain to be located on the centerline, and (3) installation of a stainless steel wire mesh entrainment separator to supplement the channel type.

3.2.3 Tanks, T-1, T-2, T-3, and T-4

All the tanks are of stainless steel, designed to be self-draining and easily cleaned. They are vapor-tight. The feed and residue tanks are furnished with Teflon gaskets, while the monitoring tanks holding relatively pure water have rubber gaskets for the removable clamped covers. The residue tank, T-2, is provided with two outlets, an upper one from which decanted solution is recycled to the evaporator, and a bottom outlet from which the settled residue is withdrawn for drumming and ultimate disposal. It is also provided with a sight glass and a steam jacket on part of the lower straight side.

3.2.4 Demineralizers, IX-1 and IX-2

The two units are Permutit Model XP-15MB Nuclear Purifiers. Each one contains 3 cu ft of nuclear grade resins. One unit holds 1 part (by volume) Permutit QH to 1.75 parts Permutit S-1, while the other holds 1 part Permutit QH to 1.75 parts Permutit SK. The latter mixture will adsorb cobalt preferentially.

3.2.5 Process and Utility Connections

Required process connections are:

1. Waste water feed - 3/4 in. NPT
2. Return to waste storage - 1 in. NPT
3. Decontaminated water outlet - 1/2 in. NPT
4. Sludge removal drum - 3/4 in. NPT
5. Vent gases (approximately 10 CFM at 0-3 in. water vac.) - 1 in. NPT.

Required utility connections are:

1. Steam - 600 lb/hr at 90 psig, dry and saturated - 1 in. NPT

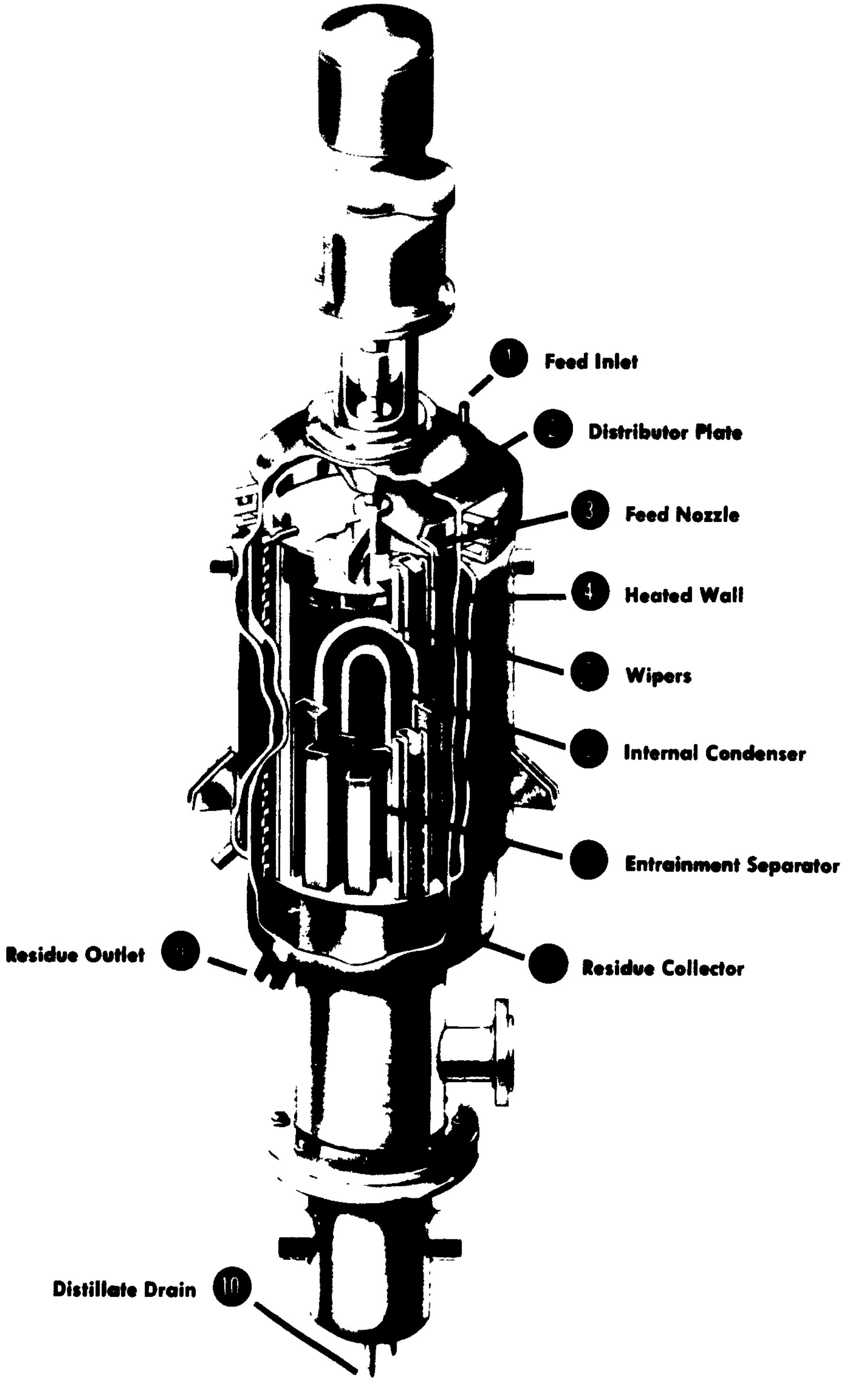


FIGURE 6. PFAUDLER WIPED FILM EVAPORATOR (STANDARD DESIGN).

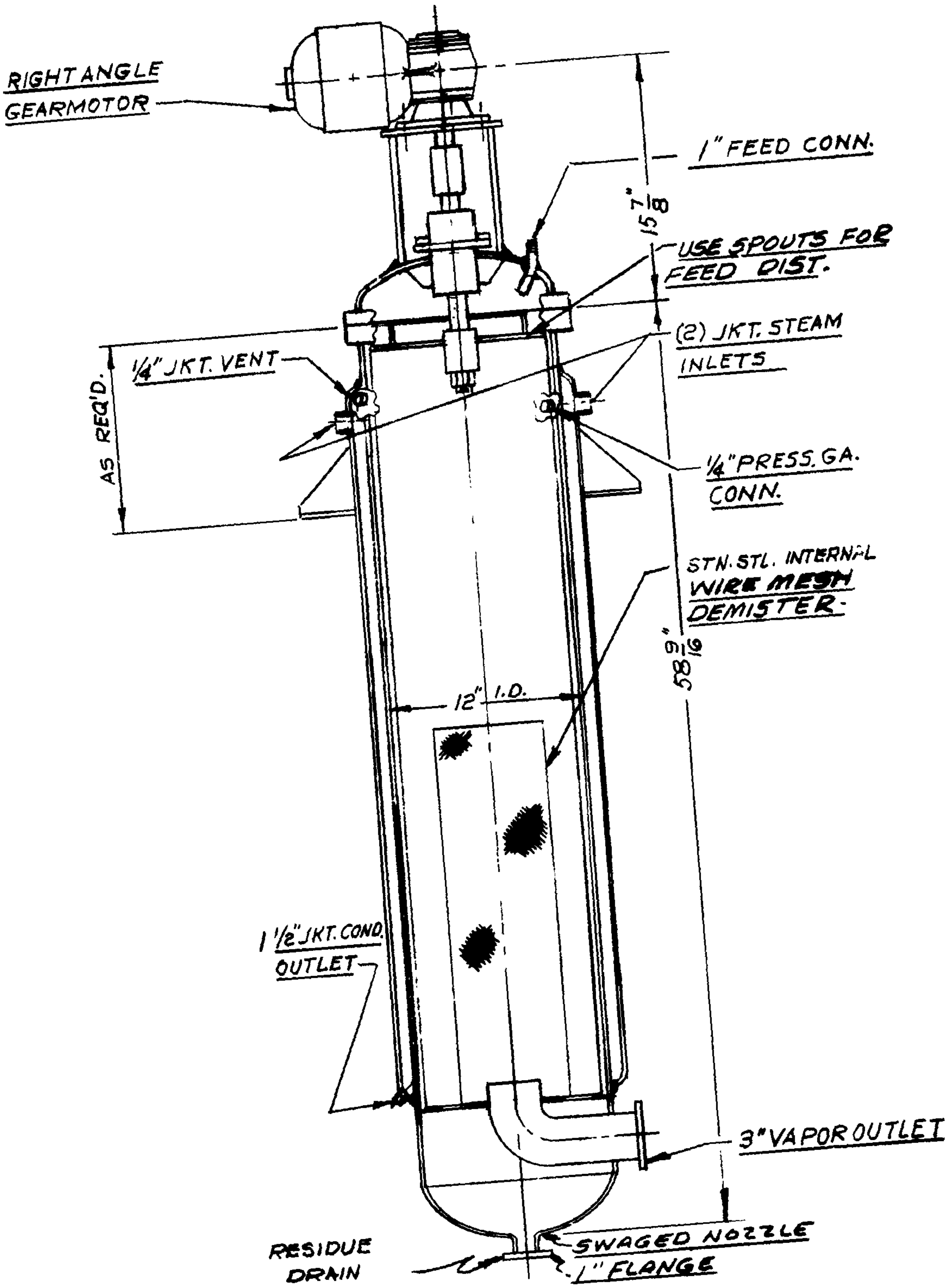


FIGURE 7. MODIFIED WIPED FILM EVAPORATOR DESIGN FOR RADIO-ACTIVE WASTE SERVICE. (CE-8244-2)

2. Cooling water supply - 80 gpm at 85°F - 2 in. NPT

3. Cooling water return - 2 in. NPT

4. Electricity - 5 amp, 3 phase, 208-220 volt, 60 cycle - three No. 12 wires (Main disconnect switch to be furnished by user.)

5. Compressed air - 3 SCFM at 25 psig - 3/8 in. copper tubing.

3.2.6 Painting and Insulation

As a precaution in the event of spills or leaks, all surfaces subject to rusting or attack by acidic decontaminating solutions were painted with one or two coats of a rust-resistant primer, followed by Amercoat 33 horizon blue, a paint recommended for ease of decontamination.

Conventional magnesia insulation was sealed with pitch and covered with aluminum sheathing for mechanical protection and to prevent moisture penetration to the insulation in the event of a spill.

3.3 INSTRUMENTATION AND CONTROLS

3.3.1 General

The facility is designed for semi-automatic operation requiring a minimum of operator attention. The evaporator system operates automatically except for removal of concentrated residue. After being started up, the evaporator system will operate with only occasional visual-audio checking. Make-up feed is controlled automatically by the liquid level in the residue tank.

Any of the conditions, listed below, automatically

1. sounds an alarm, AL-1,
2. closes an emergency steam valve, SSV-1,
3. stops the feed pump, P-1, and
4. stops the recycle pump, P-2.

Condition 1 - High residue density (specific gravity)
Condition 2 - Low residue density
Condition 3 - High level in feed tank
Condition 4 - Low level in feed tank.

Diversion of distillate from monitoring tank T-3A to T-3B (or B to A) is done automatically when the tank being filled reaches high level. This is also true of the demineralized water monitoring tanks, T-4A and T-4B.

3.3.2 Control Panel

A 66-in. high by 54-in. wide panel serves both as a 12 in. deep enclosure for all the electrical controls and switchgear and as a mounting board for visual indicating and recording instruments (Figure 8). It is bolted to the structural support frame so as to become an integral part of the facility. This prevents access to the back of the panel, but the front panels are mounted on piano-type hinges to permit easy access to the interior of the cubical from the front.

The front and back panels were fabricated by welded construction from 12-gauge sheet steel. This provides 0.22 in. of steel for shielding the operator from gamma radiation originating within the evaporator and the residue tank behind it. A 0.5 in. gap between the back of the panel and the frame was left in case additional shielding proves to be necessary. The exterior surface of the panel was painted with a rust-resistant primer and finished with Amercoat 33 horizon blue. The interior was painted with two coats of refrigerator white enamel.

External electrical connections are made to terminal blocks. Internal wiring connects the electrical components to the terminal blocks through open slot wiring ducts. Power wiring (to the motor starters) are black, control wiring is red (or blue), and ground wires are white. All components are identified by a symbol designation stamped onto tags mounted on or near the component.

3.3.3 Residue Density Controls

Residue density (specific gravity) is measured by the hydrostatic head of a fixed height of solution, approximately 33 in. The sensing element is a mercury manometer having a range of 10 in. of water, equivalent to a specific gravity range of approximately 0.300.

High residue density is established by positioning the set pointer of the instrument, DRA-1. When the recorder pen moves above the pointer, a SPDT electronic switch in the instrument is energized. This can occur if the air purge rate is too high or if the central overflow pipe in the feed tank is submerged on very high level, in addition to high density. It can also occur if the air purge line becomes plugged.

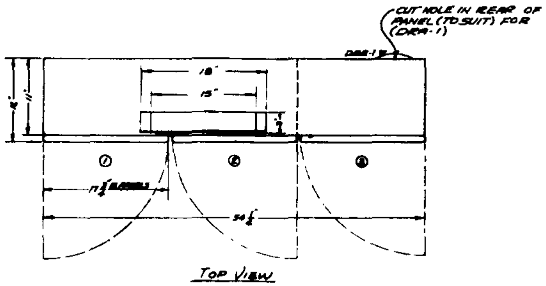
Low residue density is detected by a pressure switch, PSW-1, in the control panel. Low residue density indicates loss of upward flow of recycled residue in the overflow pipe of the feed tank. This could occur if (1) the recycle pump fails or (2) the recycle pump by-pass valve is opened too wide, or (3) residue is being removed to a sludge drum. (Low residue density itself has no significance.)

3.3.4 Feed Tank Liquid Level Control

Liquid level in the feed tank is carried between an upper and a lower probe. When the level contacts the upper probe, the high level alarm sounds, and when contact with the lower probe is lost, the low level alarm sounds.

—PANEL NAMEPLATE SCHEDULE—

#	NAMEPLATE
1	RESIDUE TEMPERATURE
2	EVAP FEED TEMPERATURE
3	EVAP FEED pH
4	RESIDUE DENSITY
5	ALARM SILENCE
6	LOW FEED RATE
7	RESIDUE DENSITY
8	FEED TANK LEVEL
9	FEED PUMP
10	RECYCLE PUMP
11	DISTILLATE PUMP
12	EVAP ROTOR
13	DEMIN. WATER PUMP
14	DENSITY PURGE HIGH
15	EVAP. FEED RATE
16	DENSITY PURGE LOW
17	DISTILLATE TANK A
18	DISTILLATE TANK B
19	DEMIN TANK A
20	DEMIN TANK B
21	HIGH
22	LOW
23	NUCLEAR DEFENSE LAB NAMEPLATE
24	PFAUDLER PERMUTIT NAMEPLATE



—PANEL LIGHT SCHEDULE—

LIGHT	COLOR	INDICATES
PL-1	RED	HIGH RESIDUE DENSITY
2	AMBER	LOW RESIDUE DENSITY
-3	RED	HIGH FEED TANK LEVEL
4	AMBER	LOW FEED TANK LEVEL
-5	GREEN	FEED PUMP RUNNING
-6	GREEN	RECYCLE PUMP RUNNING
-7	GREEN	DISTILLATE PUMP RUNNING
-8	GREEN	DEMIN. WATER PUMP RUNNING
-9	GREEN	EVAP. ROTOR RUNNING
-10	AMBER	DISTILLATE TANK A-FULL
11	AMBER	DISTILLATE TANK B-FULL
-12	GREEN	DISTILLATE TANK A-FILLING
-13	GREEN	DISTILLATE TANK B-FILLING
-14	AMBER	DEMIN. WATER TANK A-FULL
-15	AMBER	DEMIN. WATER TANK B-FULL
16	GREEN	DEMIN. WATER TANK A-FILLING
-17	GREEN	DEMIN. WATER TANK B-FILLING
-18	FLASHING RED	LOW FEED RATE

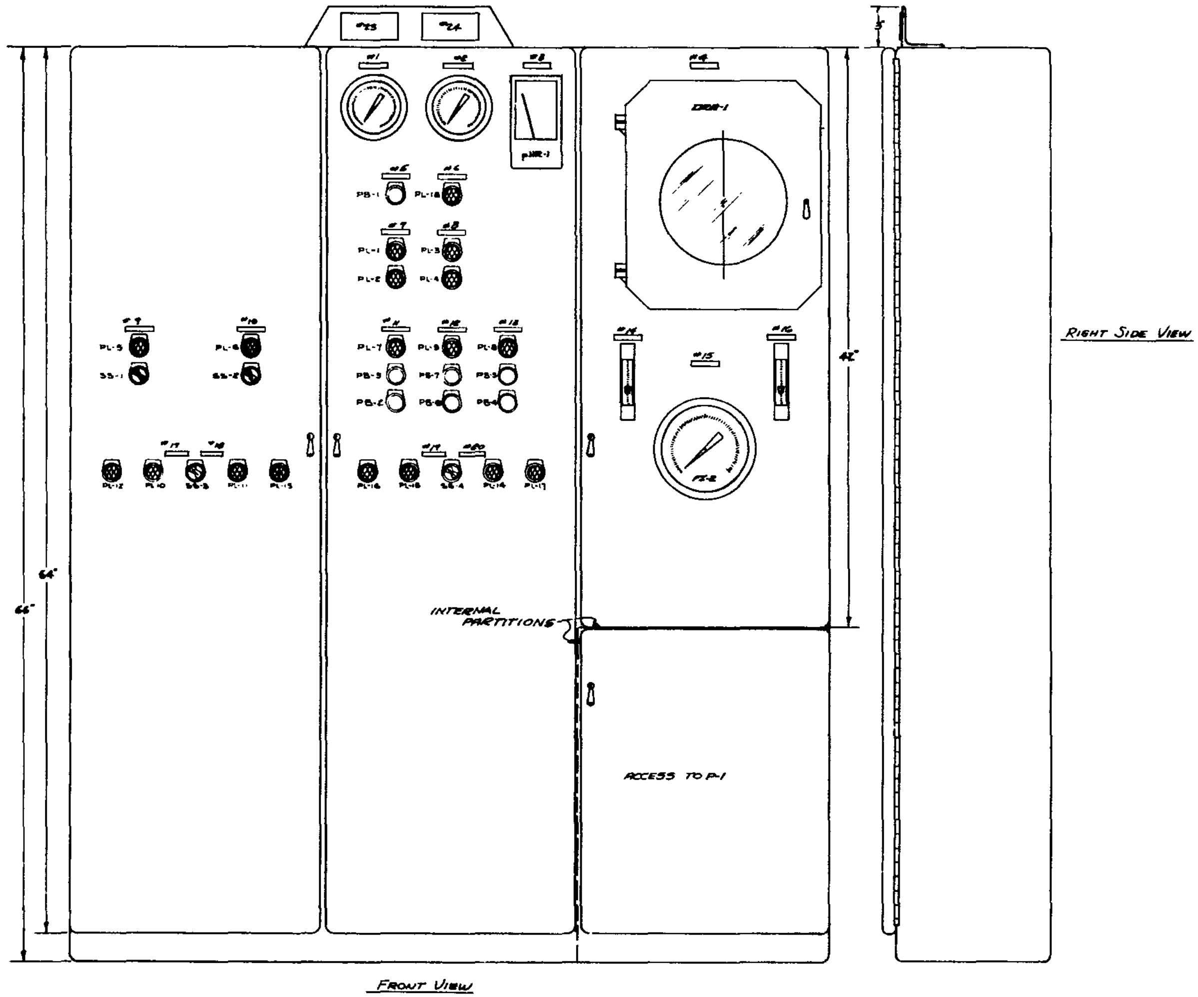


FIGURE 8. CONTROL PANEL FOR SEMI-FIXED LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY. (JC-1200-8-3)

3.3.5 Other Controls

Automatic emergency controls stop the feed and recycle pumps only if their selector switches are on "automatic".

Should the recycle pump be off for any reason whatsoever, SV-3 will be de-energized to close the steam valve, SSV-1. This also occurs in the event of either electric power failure or instrument air failure.

3.3.6 Evaporator Feed Rate

Evaporator feed rate is measured by a venturi meter, FI-2A, and a differential pressure indicator, FI-2, on the panel. The differential pressure is transmitted by a liquid system. Seal pots and a light sealing fluid (kerosene) are used to prevent any contaminated solution from reaching the control panel.

3.3.7 pH Recorder

This instrument indicates and records the pH of the feed. If the pH is below neutral, and chlorides are present in the water, there is a possibility of chloride stress corrosion occurring in the stainless steel equipment. To avoid this, caustic soda or other base may be added to the residue tank to neutralize the feed entering the evaporator.

3.3.8 Monitor Tank Controls

Distillate from the condenser, C-1, (and effluent from the demineralizers, IX-1 and -2) flows either to tank A or tank B depending on whether the pneumatic actuator of the 3-way diversion valve, LSV-1 (or LSV-2) is pressurized or vented. Liquid level probes are installed in each monitoring tank to sense high water level. When one monitoring tank becomes full, the level control will automatically divert the water flow to the other tank. Selector switches SS-3 (and SS-4) make possible manual diversion of flow from A to B or from B to A by simulating at the panel the switching action of liquid level contact with the tank probes.

4. SHIPMENT AND INSTALLATION

4.1 SITE REQUIREMENTS

The site for the facility should be at least 20 ft x 16 ft in size and essentially level. It should be capable of supporting 200 lb/sq ft of live loads or 6000-pound concentrated loads under the leveling lugs. Headroom over the area should be 12 ft with additional room over the evaporator, E-1, for removal and installation of the rotor and drive assembly. Total headroom for this operation is 12 ft plus that required for a 1-ton hoist and hook above, or about 14 ft.

4.2 HANDLING

The unit can be moved short distances by a 4-ton crane or two fork trucks (Figure 9). If a crane is to be used, a brace should be placed between the frame support for the evaporator and for the feed tank. Chain slings may then be hooked into the corner lifting lugs. If fork trucks are used, one will be at each end or each side. For very short distances or for maneuvering into place, the assembly can be placed on pipe rollers and pushed or pulled with one truck.

4.3 PREPARATION FOR SHIPMENT

The following operations must be performed to ready the facility for shipment.

1. Disconnect process and utility lines.
2. Drain all water from tanks and pipelines.
3. Drain water from the seal pots.
4. Remove
    a. evaporator feed thermometer (TI-2) bulb, and secure it to the frame.
    b. pH recorder and probe (the probe should be immersed in distilled water placed in the plastic probe cap) for separate shipment.
    c. oil cup of evaporator.
    d. leveling jack bearing plates, and raise the bolts.
5. Tighten supports of the Taylor density recorder, DRA-1.
6. Wedge a wooden brace between the support for the evaporator and for the feed tank.
7. Cover the whole unit with a tarpaulin and secure a wooden slat across the front of the control panel with a steel band to keep its doors closed and to serve as a protective bumper.

FIGURE 9. HANDLING SEMI-FIXED LIQUID RADIOACTIVE WASTE DISPOSAL FACILITY AT NUCLEAR DEFENSE LABORATORY. (U. S. Army Photograph 23-432-5/A1-61)

4.4 INSTALLATION

When the facility is unloaded at a new site, the following steps must be performed to install the facility and to make it ready for operation.

1. After the unit has been positioned on its foundation slab, the entire unit is leveled by means of the six jack screws. The unit is correctly leveled when the evaporator support posts are plumb as shown by a spirit level.

2. Install
   a. evaporator feed thermometer bulb.
   b. pH recorder and probe, after recalibration.
   c. nameplate bracket on control panel.
   d. oil cup of evaporator, after filling with oil.

3. Loosen the supports of the Taylor density recorder, DRA-1, and level the instrument.

4. Remove the brace between the supports of the evaporator and the feed tank.

5. Fill the seal pots.

6. Make five process connections (see section 3.2.5).

7. Make five utility connections (see section 3.2.5).

4.5 SYSTEM CALIBRATION FOLLOWING INSTALLATION

For intelligent operation and evaluation of the facility, calibration curves are required for the tanks and instruments. Those for the tanks, i.e., volumetric capacity vs. depth of liquid, will be permanent and need to be verified only once. However, calibration curves for the instruments must be checked at periodic intervals, or whenever reason for doubting the accuracy of the instrument readings exists. In general, this should be done by checking the reading by an independent and thoroughly reliable procedure. For example, the density or specific gravity record may be compared with that given by a hydrometer on samples taken from the line, and the pH record may be compared with that given by a laboratory instrument. The fresh feed rotameter and the evaporator feed venturi meter may be checked simultaneously by diverting the entire recycle flow to a receiver drum while measuring the volume change in the feed tank during timed intervals.

5. OPERATION OF FACILITY

5.1 DESCRIPTION OF OPERATION

Reference Drawing: Flow Diagram, Figure 5.

Waste water from Government storage tanks in the outside pit is drawn through a 3/4 in. feed line to the self-priming feed pump, P-1. This pump then elevates it to the feed tank, T-1. Rate of flow to T-1, as indicated by the rotameter, FI-1, is held to a maximum of about 1 gpm by a manually positioned valve. The flow is further reduced by control valve, LCV-1, which opens on low level in the residue tank, T-2, and closes on high level. This control prevents evaporation to dryness or flooding of the system by adjusting the fresh feed rate to maintain a constant level of solution in T-2.

Concentrated solution is pumped from T-2 to T-1 at a nearly constant rate by P-2. It overflows from a 2 in. pipe inside of T-1 to mix with fresh dilute feed. The mixed solution flows by gravity from T-1 to E-1 through a venturi flow indicator, FI-2, and around a pH electrode. The pH of the solution is recorded on the control panel. Should this value be too low, the operator will add caustic solution from a bottle feeder, T-5, to T-2.

Solution flows down the inside of the steam heated walls of the evaporator, E-1. Residue drains from E-1 to the residue tank, T-2, and water vapor passes through the internal separators of E-1 to the external separator, S-1.

Specific gravity of the concentrate is measured by bubbling air slowly into the bottom of the 2 in. concentrate overflow pipe of T-1. The air pressure required to obtain bubbling is equal to the hydrostatic head which, because of the fixed liquid leg, is a direct measure of specific gravity. Specific gravity measured in this way is recorded by DRA-1.

When the specific gravity of the concentrate reaches a predetermined value, the operator takes a sample. If on cooling to below 100°F the sample solidifies, then the flow of concentrate from T-2 to T-1 is diverted manually, in whole or in part, to a 55-gallon drum. When concentrate is being pumped to a sludge receiver drum, the bottom outlet valve of T-2 should be opened so that the more concentrated solution and solids which settle in the bottom of T-2 will be pumped to the drum.

After removing sufficient concentrate, the bottom outlet of T-2 and the concentrate drain valve to the drum are closed. This removal of concentrate or sludge may be done without interruption of the evaporating process. The record shown by DRA-1 will be one of slow increase in specific gravity during concentration with an abrupt decrease when sludge is removed. DRA-1 includes an alarm which will sound when the apparent specific gravity becomes too high or too low. High level could also be due to flooding of T-1. Low level would occur in the event of failure of P-2.

Water vapor produced in the evaporator passes through two internal separators and exits to the external separator, S-1. Any liquid which collects in S-1 drains back into T-2. From S-1 the vapor goes to the condenser, C-1. Water condensed in C-1 drains into either of the two distilled water receiver tanks, T-3A or T-3B. A 3-way air operated valve, LSV-1, directs the flow to either T-3A or T-3B. A probe type level switch in T-3A and in

T-3B is the primary sensing device which controls the air supply to LSV-1. These will operate to change the direction of flow from the tank being filled to the other on high level. An alarm will sound when the switchover takes place. A manual push button must be operated to turn off the alarm.

While a distilled water receiver tank is filling, a sample of the distillate is taken by a constant drip into a sample bottle. After the tank has filled, the sample of distillate is analyzed for activity. If the activity level is too high to permit discharge to waste, the operator pumps the distilled water via P-3 through the demineralizers, IX-1 and IX-2, to achieve further decontamination. The piping for the demineralizers, IX-1 and IX-2, is so arranged as to allow them to be used in series or in parallel.

Demineralized water is collected in either of the two 300-gallon monitoring tanks T-4A or T-4B. As in the case of the distilled water, a 3-way air-operated valve will divert the demineralized water to the other tank and sound an alarm each time a tank fills to the level of the sensing probe. After the activity of the demineralized water collected in a monitoring tank has been determined, the contents of the tank are pumped by P-4 either to waste or back to T-3A or T-3B.

5.2 OPERATING PROCEDURES

5.2.1 General

In the design of this facility, it was assumed that at least one operator would be present at all times during the operation of the facility. The system is not intended to operate completely automatically. However, the equipment and its controls were so arranged that a minimum of operator-attention would be required. Detailed instructions for the operation of this facility have been prepared in a separate operating manual, which must be consulted for details.

5.2.2 Preparing for Startup

To prepare the facility for initial operation, it is necessary to turn on the instrument air supply and check for proper operation of pneumatic controllers and valves. With all operating switches in the off position, the switch controlling electric power to the facility may be closed.

5.2.3 Initial Filling of an Empty System

With all normally closed valves in the closed position, the feed pump is started manually to start the flow of waste solution to the system. Initially the feed is allowed to flow into the residue tank until the level control shows an indication that level of the waste has reached the level control float. Then valves are closed to direct the flow directly to the feed tank. When the level in the feed tank is such that overflow to the evaporator is imminent, the evaporator is ready to be started.

5.2.4 Starting Evaporator After Overnight Shutdown

Selector valves are set and the recycle pump is started manually to begin the recycle stream. The evaporator is then started and instruments are checked for the proper

operation of the mechanical equipment. When the operator is satisfied that the system is functioning smoothly, the main steam valve and condensing water valves are opened. The system will now operate automatically with the discharge of decontaminated distillate from the condenser and an accumulation of concentrated residue in the residue tank. Eventually the monitoring tank previously selected to receive the condensate will fill, whereupon the diverting valve will shift the flow to the other tank. A sample may be drawn from the full tank for radioanalysis.

5.2.5 Disposition of Distillate

The radioanalysis of the contents of the full monitoring tank will take about 6 to 8 hr because of the extremely low level of activity. Depending on the analysis a decision must be made either to discharge the distillate to the sewer, if it meets MPCU requirements, or to demineralize the distillate for further decontamination. If the distillate is to be discharged to sewer the selector valves are properly positioned and the distillate pump is started, discharging the water to waste. If it is necessary to demineralize the distillate, the selector valves are properly positioned, the distillate pump is started, and the water is passed through one or both demineralizers. In general, series flow through both will accomplish maximum decontamination. The effluent from the demineralizers flows into a final monitoring tank.

5.2.6 Disposition of Demineralized Water

The same procedure is employed for the demineralized water as for the distillate. A sample is drawn during processing, analyzed for residual activity, and if found acceptable under MPCU requirements, the demineralized batch is sent to waste. If it becomes necessary for further decontamination to be performed, the demineralized water may be recycled through the demineralizers or even through the evaporator. Experience to date with fairly low-level waste indicates that distilled water will be under allowable discharge activity and may be pumped to waste with the distillate pump.

5.2.7 Routine Shutdown of Evaporator

At the end of the shift, when it is desired to shut down the evaporator overnight, the feed pump is stopped. The valve controlling the flow of residue into the sludge drum may be opened momentarily to discharge part of the residue. For each 200 gal of distillate collected this valve should be opened for about one minute to get a 100 to 1 concentration ratio.

The main steam valve is closed and the recycle pump stopped. The evaporator rotor is also stopped. The feed tank is drained into the residue tank. To avoid the plugging of lines while shut down, steam may be allowed to flow to the steam jacket on the residue tank and the steam traced piping. The condenser water is stopped and the electric power and air supply shut off.

5.3 SAFETY AND EMERGENCY PROCEDURES

The general approach in the design of the system has been to provide for indication of abnormal conditions and, where necessary, shutdown of certain equipment. Because

of the proximity of the operator to the facility, he will easily be informed of an abnormal condition by alarm signals and red panel lights. Alarm conditions are announced by both visual and audible signals depending on the emergency condition that initiates the signal. When an alarm is initiated, the steam valve closes. This action stops the evaporation of distillate.

5.4 MAINTENANCE

The equipment constituting the waste disposal facility requires direct maintenance from time to time. In general this will mean routine inspection and lubrication of moving parts. The Wiped Film Evaporator is provided with an oil cup for the rotary shaft seal which will need to be filled periodically. The gear drive for the rotor on the evaporator will also need periodic oil changes and inspection.

The only parts that appear to require inspection and replacement on account of wear will be O-rings which act as shaft seals for the feed pump and the recycle pump, and the wiper blades in the evaporator. Wear of the wiper blades depends on uncertain factors such as abrasive content of the feed, operation of the evaporator with the walls dry, and length of operation. It is anticipated that the wiper blades will have a life exceeding one year. However, it is desirable that several times each year the rotor of the evaporator be raised to allow inspection of the wiper blades. In the event they are worn excessively (worn to the root of the slots), they may easily be replaced.

The system has been designed with standard commercial equipment of the highest quality. Nevertheless it is expected that components will require replacement from time to time as they wear out or become damaged. All equipment items may readily be replaced with identical spares available commercially.

6. TESTING AND EVALUATION

6.1 GENERAL

The facility was assembled in the Rochester plant of The Pfaudler Co. where it underwent initial mechanical checking and tests. No major flaws were found in the design, although small design changes and improvements had to be made. It was determined at this time that all mechanical equipment functioned satisfactorily and instruments and controls operated normally. Preliminary tests were run on tap water and then on simulated waste to determine whether equipment malfunctions would occur with a flocculent waste in the residue tank and evaporator. These tests produced no abnormal conditions and the facility was prepared for shipment, without incident, by truck to the Nuclear Defense Laboratory at Army Chemical Center, Maryland. A series of tests was initiated at Nuclear Defense Laboratory to determine that the facility complied with the specifications.

6.2 OPERATION WITH CLEAN WATER FEED

First testing was done with essentially clean nonactive feed water. During these tests the cylindrical float of the residue tank liquid level controller, LC-1, was replaced with a ball float to be sure that the level in the residue tank would never fall below the upper outlet. The O-ring seals on the recycle pump, P-2, were replaced two or three times because this pump developed a serious leak shortly after start-up. This problem of leakage was not solved until later, when grooved O-rings were installed. The mineral oil sealing liquid used initially for the venturi meter, FI-2, was replaced with fuel oil to obtain more rapid response. Several small leaks in the piping system were eliminated by tightening or remaking joints.

6.3 OPERATION WITH UNDISSOLVED SOLIDS

To simulate operation with a highly concentrated solution, hydrated lime, soda ash, and ferric nitrate were added successively to the feed water. The only problem encountered when a slurry of hydrated lime was used as feed was plugging of the feed line strainer. The finely divided, rapid-setting lime formed a paste in the strainer. After soda ash (sodium carbonate) was added to the feed, a hard, abrasive scale of calcium hydroxide precipitated in the system. This plugged the evaporator residue drain line completely so that it had to be cleaned mechanically.

After most of the lime had been removed from the evaporator system a solution of soda ash alone was used as feed. Later, ferric nitrate was added which produced copius flocculent precipitates of ferric hydroxide. This type of precipitate in no wise hampered operation of the system except perhaps for some nuisance accumulation in the seal pots of FI-2. It did provide easily observed evidence of small leaks which were then tightened, and it also showed that the residue tank served quite well as a settling-decanter.

Difficulty was experienced at this time with operation of the canned pumps for distilled and demineralized water. They were both remounted in vertical position to eliminate priming difficulties.

Another minor problem was due to high sensitivity in the demineralized water level controls. This problem was resolved by isolating the control wiring from other circuits in the panel to eliminate false signals by induction.

6.4 OPERATION WITH RADIOACTIVE FEED

Before commencing operations with radioactive feed, a small condenser was installed in the vent lines from the residue and feed tanks. This was only partially successful in preventing the spread of activity through the vent system to the monitoring tanks. Separate vent lines were later installed for the monitoring tanks, and the plastic vent lines from the feed and residue tanks were replaced by stainless steel piping.

Operation with radioactive feed introduced a new operating factor since the storage tanks for the contaminated feed were located outdoors and underground. The feed pump, although classed as a self-priming pump, had to be primed before it provided the necessary suction lift when operated at its lowest speed.

Thermal and evaporation rate data taken during these operations are presented in Table 1. These data show that the facility is capable of processing about 300 gal of waste liquid per 8 hr. This is twice the specified minimum capacity.

Radioactivity data are presented in Table 2 and shown graphically in Figures 10 and 11. These data show that the evaporator was effective in decontaminating the feed, but appear to indicate that demineralization was not effective. In fact, the activity of demineralized distillate is, in general, greater than that of the distillate. This anomalous result must have been caused by spread of activity through the common vent piping. This piping has since been separated and pitched for correct drainage, and demineralization is now effective in further decontamination.

The feed solution used on January 11 was taken from a tank which contained exactly 1000 gal of solution and to which a liter of Co-60 nitrate solution containing 3.3 mc of beta activity has been added. The activity concentration in this tank was, therefore, at least

$$\frac{3.3 \times 10^3 \mu c}{3.785 \times 10^6 \text{ ml}} = 8.7 \times 10^{-4} \mu c/\text{ml (beta)}$$

Beta activity in two samples of distillate was 3.6×10^{-9} and $3.1 \times 10^{-9} \mu c/ml$. This corresponds to a DF of 2.4×10^5 and 2.8×10^5, respectively.

Activity in the demineralized water samples was $3.9 \times 10^{-9} \mu c/ml$ in one sample and below background ($<10^{-10} \mu c/ml$) in the other. This corresponds to a DF of 2.2×10^5 and $>8.7 \times 10^6$, respectively.

These data are believed to be the best available to date on the decontaminating performance of the facility. The results are conservative since activity present in the original 1000 gal of feed and activity that spread through the vent piping system have both been ignored.

TABLE 1. DAILY OPERATING DATA FOR WASTE DISPOSAL FACILITY.

		Evaporator		Steam			Condenser		
Date Jan 1962	Total Distillate, gal	Rate gph	Duty Btu/hr[a]	Pressure psig	Rate lb/hr	Duty	Temperature Rise, °F	Rate gpm	Duty[c]
10	588	50	460,000	67	480	430,000[b]	28	26	364,000
11	588	47	440,000	67	480	430,000[b]	28	26	364,000
11							18	42	378,000
12	280	48	450,000	67	480	430,000[b]	18	42	378,000
15	280	46.5	430,000	67	480	430,000[b]	18	42	378,000
16	280	46	430,000	67	480	430,000[b]	19	42	400,000
17	170	46.5	430,000	67	480	430,000[b]	20	42	420,000
18	280	41.5	390,000	67	480	430,000[b]	21	42	440,000
19	255	45	420,000	67	480	430,000[b]	20	42	420,000
22	208	36	335,000	49	415	380,000[d]	24	30	360,000
23	136	40	370,000	49	415	380,000[d]	18	42	380,000
24	175	37.5	350,000	49	415	380,000[d]	18	42	380,000
25	212	37	340,000	49	415	380,000[d]	19	42	400,000

[a] 9300 Btu/gal.
[b] 900 Btu/lb (latent heat only).
[c] 500 Btu/gpm-°F.
[d] 912 Btu/lb (latent heat only).

TABLE 2. DAILY ACTIVITY ANALYSES FOR WASTE DISPOSAL FACILITY.

Date Jan 1962	β - Activity Residue	β - Activity Evaporator Feed	β - Activity Distillate	β - Activity Demineralized Water	α - Activity Residue	α - Activity Evaporator Feed	α - Activity Distillate	α - Activity Demineralized Water
10	-	8.2×10^{-4}	$<10^{-10}$	9.4×10^{-9}	-	4.3×10^{-7}	$<10^{-11}$	1.5×10^{-9}
10	-	8.2×10^{-4}	$<10^{-10}$	9.7×10^{-10}	-	4.3×10^{-7}	2.4×10^{-9}	$<10^{-11}$
11	1.1×10^{-3}	8.3×10^{-4}	3.6×10^{-9}	3.9×10^{-9}	1.6×10^{-7}	1.1×10^{-7}	1.0×10^{-9}	1.1×10^{-9}
11	1.1×10^{-3}	8.3	3.1×10^{-9}	$<10^{-10}$	1.6×10^{-7}	1.1×10^{-7}	1.2×10^{-9}	1.3×10^{-9}
12	3.2×10^{-4}	4.6	1.4×10^{-9}	5.7×10^{-8}	7.6×10^{-8}	9.2×10^{-8}	1.3×10^{-10}	5.3×10^{-10}
15	4.4×10^{-4}	2.9	1.2×10^{-9}	2.0×10^{-8}	6.1×10^{-8}	2.1×10^{-7}	8.6×10^{-10}	$<10^{-11}$
16	6.8×10^{-4}	6.3	$<10^{-10}$	2.5×10^{-9}	6.7×10^{-7}	2.0×10^{-7}	$<10^{-11}$	1.6×10^{-9}
17	9.3×10^{-4}	6.3	3.7×10^{-8}	1.4×10^{-8}	1.4×10^{-7}	6.1×10^{-8}	5.1×10^{-10}	9.2×10^{-11}
18	1.0×10^{-3}	3.4	2.8×10^{-9}	1.4×10^{-8}	2.3×10^{-7}	2.6×10^{-7}	4.1×10^{-10}	9.2×10^{-11}
18	1.0×10^{-3}	3.4	1.5×10^{-9}	-	2.3×10^{-7}	2.6×10^{-7}	1.8×10^{-10}	-
19	6.4×10^{-4}	4.1	$<10^{-10}$	-	9.2×10^{-8}	9.2×10^{-8}	$<10^{-11}$	-
22	6.4×10^{-4}	4.1	$<10^{-10}$	3.4×10^{-9}	9.2×10^{-8}	9.2×10^{-8}	$<10^{-11}$	$<10^{-11}$
23	4.0×10^{-4}	2.3	5.6×10^{-9}	3.4×10^{-9}	4.3×10^{-5}	$<10^{-11}$	$<10^{-11}$	$<10^{-11}$
24	3.3×10^{-4}	2.1	9.1×10^{-10}	-	1.1×10^{-7}	$<10^{-11}$	7.7×10^{-11}	-
24	-	-	9.1×10^{-10}	-	-	-	7.7×10^{-11}	-
25	-	-	-	-	-	-	-	-

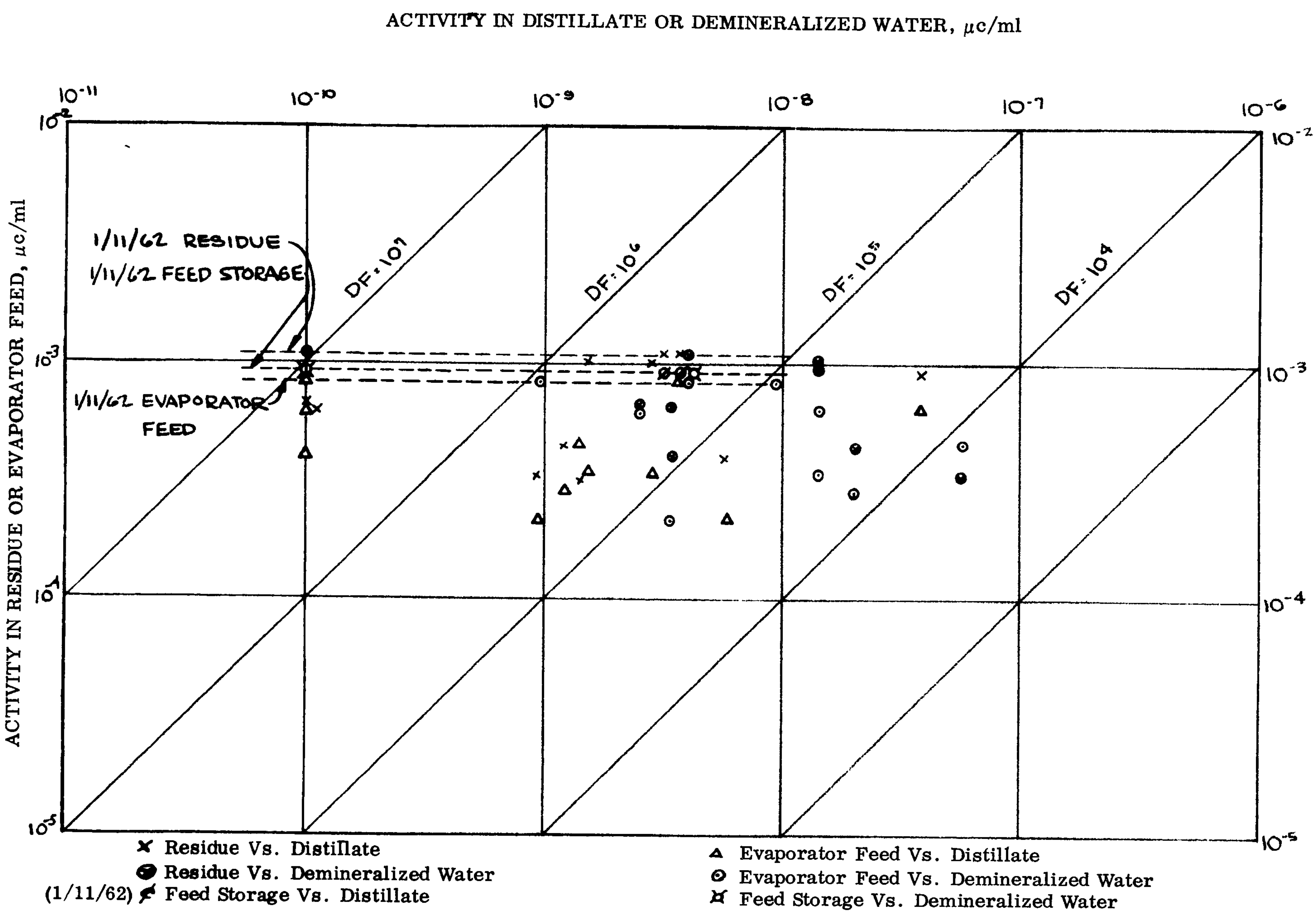


FIG. 10. DECONTAMINATION FACTORS FOR BETA ACTIVITY.

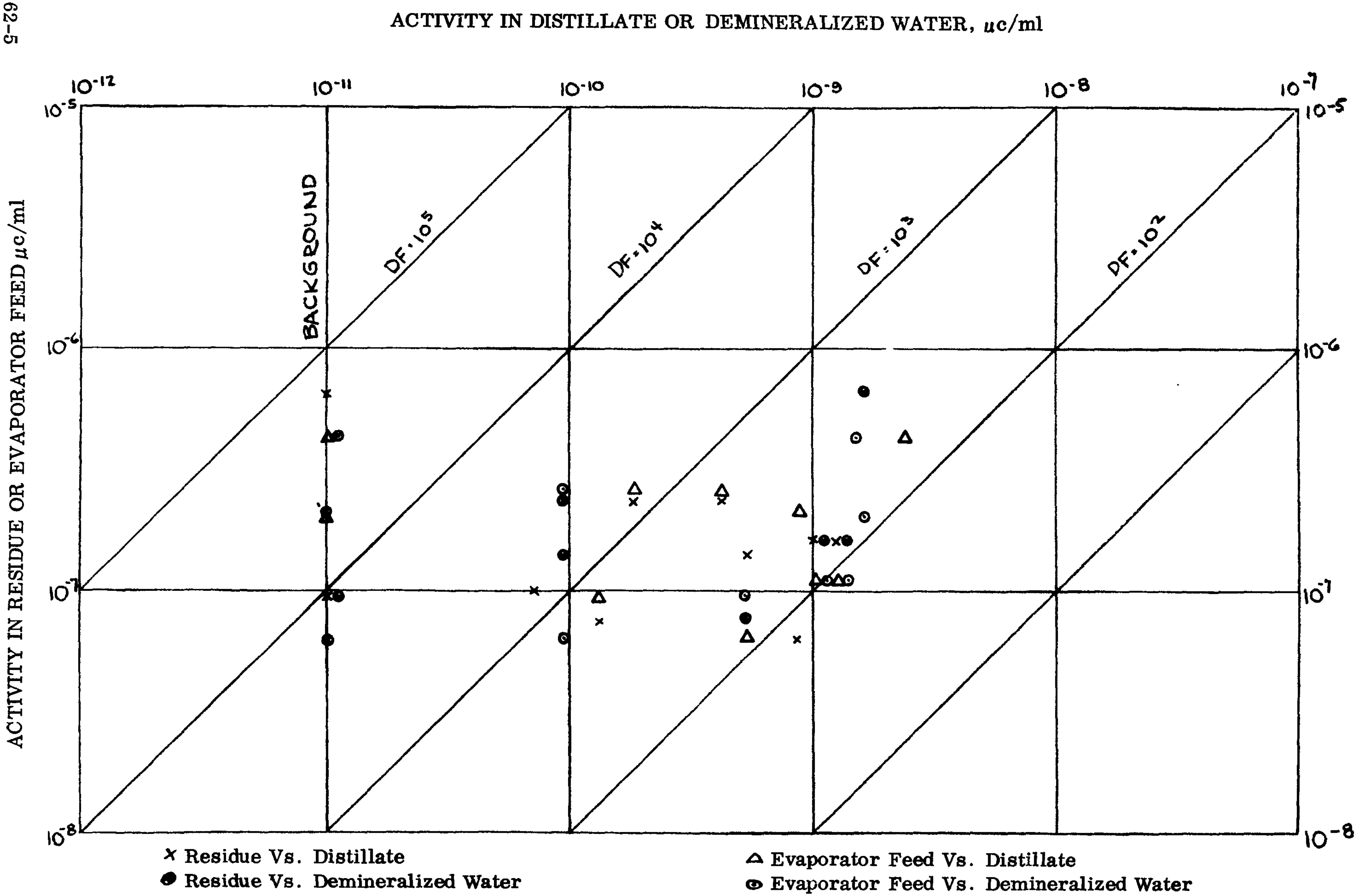


FIGURE 11. DECONTAMINATION FACTORS FOR ALPHA ACTIVITY.

Beta activity in the distillate exceeded $10^{-8}\mu c/ml$ only once. The highest activity reported for alpha activity in the distillate is $2.4 \times 10^{-9}\mu c/ml$.

High activity in the demineralizer effluent makes the average decontamination factor (DF) appear to be about 10^5 for beta activity and 5×10^2 for alpha activity. However, the average DF for evaporation alone is much closer to 10^6 for beta activity and 10^3 for alpha activity. It is felt that measures which have been taken to control the spread of activity through the vent piping will materially improve these initially promising results.

These data on decontamination must, of course, be regarded as preliminary. Additional testing by the Army using solutions of higher activity is necessary to determine the full capabilities of the facility and the effect of prolonged operation upon activity and solids build-up.

6.5. CONCENTRATION FACTOR

The volume of sludge collected from the first 10,000 gal of feed waste processed in the facility is only slightly greater than 100 gal. The indicated concentration factor is, therefore, approximately 100, or stated in another way; the volume of sludge to be ultimately disposed of in drums is about 1% of the original dilute radioactive waste.

7. CONCLUSIONS

7.1 DESIGN

A semi-fixed liquid radioactive waste disposal facility has been designed and developed in accordance with specified performance requirements. The design complies with portability requirements, height and weight limitations, and other mechanical specifications.

7.2 PERFORMANCE

As a result of the tests and evaluations run on radioactive waste at the Army Chemical Center, it has been determined that the semi-fixed liquid radioactive waste disposal facility is capable of treating a variety of radioactive liquid wastes having activity levels as high as $10^{-1} \mu c/ml$, achieving an overall decontamination factor of at least 10^7. The system is capable of decontaminating approximately 300 gal of waste in an 8-hour day including startup, sludge removal, and shutdown. The disposal facility complies in every respect with the performance requirements originally specified.

7.3 FURTHER TESTING

Higher-activity waste must be employed in additional performance tests in order to determine the limits of the decontamination capability of the entire system (evaporator and demineralizers).

8. RECOMMENDATIONS

This section contains recommendations for design changes that should be considered for future facilities of this type.

8.1 SEMI-FIXED DESIGN

Although there do not appear to be any serious defects in the existing design, a number of improvements are possible. The structural supports for the evaporator and feed tank should be interconnected at the top so that temporary bracing is not required for handling by crane. Transport over public highways would be simplified if the overall width was 8 ft instead of 10 ft. If analytical procedures will permit it, the monitoring tanks could be reduced in size and number. These account for the major share of bulk displacement. In any event, the facility could be designed as two modules, one consisting of the evaporator and demineralizer systems, and the other of the monitoring tanks. The modules may readily be connected in the field.

8.2 EVAPORATIVE SYSTEM

This system has proved to be satisfactory in most respects. There are, however, a few weaknesses which should be corrected in future facilities. It should be possible to hold the feed rate to the evaporator constant over extended time intervals. This can be done by introducing fresh feed to the suction side of the recycle pump. This means that specific gravity measurement would have to be made upstream from this point, probably in the residue tank, but it also could eliminate the need for a feed pump by introducing fresh feed to the suction side of the recycle pump. This would require that the feed control valve, LCV-1, be placed in the recycle line ahead of the feed point, or even that a 3-way valve be used for this purpose. The recycle pump should then be a variable speed positive displacement pump. This arrangement should also assure more positive priming of the feed pump.

A long evaporator residue drain line should be avoided. Consideration should be given to placing the residue receiver directly below the evaporator. With gravity feed to the evaporator, flow is temporarily checked when boiling starts. When this happens, the wiper blades may rub on a dry surface and generate noise. This is undesirable, but not serious. It could be overcome by having the recycle pump force feed directly to the evaporator. However, this would mean that if the recycle pump failed for any reason, all feed would be lost instantly and tail-end flow would evaporate to dryness on the hot walls of the evaporator. This is most undesirable. A better procedure would be to equalize the pressures within the evaporator and the feed tank.

The evaporator feed tank need be only large enough to sustain flow to the evaporator for 5 to 10 min after a recycle pump failure.

The residue receiver served effectively as a settling tank. This is desirable. A cone bottom should also be considered for this tank. The upper outlet and the level controller should be located relative to each other so that a cylindrical float or displacer could be used to give a wider throttling range.

8.3 INSTRUMENTATION AND PIPING

The range of the specific gravity instrument, DRA-1, 1.10 to 1.40 is too high. A better range would be 1.00 to 1.30. A 24-hour clock should also be used for the recorder.

The venturi sensing element and seal pots for the evaporator feed indicator, FI-2, are desirable, but a pneumatic or electronic transmitter should be used in place of a seal liquid system to transmit the differential pressure to the instrument panel.

Means should be provided to keep the glass electrode of the pH recorder, pHR-1, wet at all times.

8.4 MONITORING SYSTEM

These tanks served their purpose well. More experience may show that their 300-gallon capacity is larger than necessary, but this large capacity was needed during around-the-clock operation. Needle valves rather than ball valves should be used at sampling points for distilled and demineralized water.

APPENDIX A

DETAILS OF THE FACILITY

A.1 LIST OF DRAWINGS

The following drawings were prepared for this project.

PROJECT DRAWINGS

JC-1200-1-9	*Flow Diagram
JC-1200-6-3	Line Diagram - Electrical Controls
JC-1200-8-3	*Control Panel
JC-1200-9-3	Control Panel - Parts Layout
JC-1200-10-3	Plot Plan
JC-1200-20-3	*Equipment Layout
JC-1200-24-5	Process Piping Layout
JC-1200-25-1	Utility Piping Layout
R561-0612, Sh. 1	Support Frame

*Included in this report.

PFAUDLER EQUIPMENT DRAWINGS

Item No.	Drawing No.	Item
E-1	R561-0611, Sh. 1 R561-0611, Sh. 2 R561-0611, Sh. 3	12 in. Wiped Film Evaporator Cover Assembly Demister Assembly
C-1	CE3-611073	Condenser
T-1	CE4-611074	Feed Tank
T-2	CE4-611075	Residue Tank
T-3A & 3B	CE4-611076-79	Distillate Tanks (2)
T-4A & 4B	CE4-611076-79	Demineralizer Water Tanks (2)
S-1	CE3-611080	Separator

A.2 INDEX TO CONDENSED EQUIPMENT SPECIFICATIONS

PROCESS REQUIREMENTS

		FEED	VENT	RESIDUE	DISTILLATE	CONDENSER TUBESIDE	JACKET
	Processed Material	15% Solids	Water Vapor	60% Solids		None	75 Psig Steam
DATA	Mol. Wt.		18				18
	Rate Lb/Hr	400	300	100			400 Normal (500 Design)
	Temp.	103°F	212°F	215°F			
	Sp. Gr.						
	Visc.						
	Sp. Heat						
	Th. Cond.						
	Lat. Heat		970				895
PERFORMANCE	Sens. Duty	(215-103)x400 = 45,000					
	Lat. Duty	970x300 = 290,000					
	Total Heat Duty Btu/Hr			335,000			360,000 (Normal)
	Mtd.						
	Trans. Rate						
	Fouling Fact		0.002				
CONSTRUCTION	Size	12" Dia					12 sq.ft.
	Code						ASME
	Design Temp.	350°F					350°F
	Design Press.	75 Psig or FV					75 Psig
	Test Press.	113 Psig					113 Psig
	Materials of Construction	Shell: 316 Stainless (1) Wipers: Rulon O-Rings: Silicone Rubber Gaskets: Teflon					
		FEED	VENT	RESIDUE	DISTILLATE	IN- OUT- / IN- OUT-	VENT-1/4" IN-1-1/2" OUT-1-1/2"
	Openings	1" Nipple	3" Flg	1" Flg			

Shop Order R561-0611 Drive Horiz.
Dwg. No. R561-0611 RPM 300
Shipping Wt. 865 lb. Motor Fixed Speed
Flooded Wt. 1000 lb. 1 HP,TE,60 cy/220V

Accessories
(Intern.Separator)
1-1/2" type 304 stainless steel wire mesh, metal textiles 0.011R90(304) #8 crimp

NOTES:

THE PFAUDLER CO.
PROJECT ENGINEERING
ITEM E-1
WIPED FILM EVAPORATOR

FOR U.S.Army Chemical Center
PROJECT G761-6006 DATE 5/24/61
BY WFS CHKD. REV. 12/13/61
DWG. NO. SH. 1 OF 18

ITEM NO	T-1	T-2	T-3A&3B	T-4A&4B
NAME DESIGNATION	Feed Tank	Residue Tank	Distillate Tanks	Demin. Water Tanks
MANUFACTURER	Pfaudler	Pfaudler	Pfaudler	Pfaudler
SHOP ORDER NO.	E461-1074	E461-1075	E461-1076-77	E461-1078-79
PFAUDLER ORDER NO.	"	"	"	"
DRAWING NO.	CE4-611074	CE4-611075	CE4-611076-79	CE4-611076-79
VESSEL TYPE	Vertical Clamped Top	Horizontal	Vertical Clamped Top	Vertical Clamped Top
MODEL NO.	Special "SA"	Custom	"SA"	"SA"
CAPACITY (Rated), Gals.	61	50	312	312
SIZE, Dia. x Straight Side	24"x33"	26"x22"	48"x42"	48"x42"
GASKETS (Tank)	Teflon	Teflon	Rubber	Rubber
SUPPORTS	3 - Legs	4 - Legs	4 - Legs	4 - Legs
WEIGHT, Empty (Rigging)	150 lbs.	150 lbs.	360 lbs.	360 lbs.
WEIGHT, Full (Supports)	750 lbs.	650 lbs.	3000 lbs.	3000 lbs.
AGITATION & DRIVE SHEET NO.	-	-	-	-
SERVICE				
MATERIAL OF CONSTRUCTION	304 Stainless	304 Stainless	302 Stainless	302 Stainless
FINISH or GLASS (Inside)	Mill Finish Smooth Welds	Mill Finish Smooth Welds	No.4	No. 4
DESIGN TEMP., °F.	350°F	350°F	350°F	350°F
DESIGN PRESS./VACUUM	Vapor tight only	No Pressure or Vacuum	Vapor tight	Vapor tight
CODE & YEAR	10 Psig Hydro	10 Psig Hydro	None	None
STAMPED	No	No	No	No
TOP HEAD, TYPE & THICKNESS	16 Ga Bwg	16 Ga Bwg	16 Ga Bwg	16 GA Bwg
BOTTOM HEAD, TYPE & THICKNESS	16 Ga Bwg	16 Ga Bwg	16 Ga Bwg	16 Ga Bwg
OPENINGS, Manhole or Handhole	None	6" Dia.	None	None
Top	1-2",1-1"	1-1"	2-2"	2-2"
Bottom Outlet(s)	1-1"(1)	1-1"	1-1"(1)	1-1"(1)
Other (Side)	1-3/4" 1-1/2"	1-3"F 2-1"	1-1"	1-1"
ACCESSORIES	2" Internal Overflow pipe(2)(3)	Steam heating panel	(2)(3)	(2)(3)

Notes:
(1) Channeled outlet for full drainage
(2) Gage glass
(3) Liquid level probe

THE PFAUDLER CO.
PROJECT ENGINEERING
VESSEL SPECIFICATIONS

FOR U.S. Army Chemical Center
PROJECT G761-6006 DATE 5/15/61
BY WFS CHKD REV 12/13/61
DWG NO SH 2 OF 18

ITEM NO.	C-1	
SERVICE	Condenser	
MANUFACTURER	Pfaudler	
SHOP ORDER NO.	E361-1073	
PFAUDLER ORDER NO.		
DRAWING NO.	CE3-611073	
TYPE	Fixed Tube Sheet	
MODEL NO.	605	
INSTALLED POSITION	15 Deg. w horizontal	
HEAT TRANSFER SURFACE	25 Sq. ft.	

PERFORMANCE

	SHELL SIDE	TUBE SIDE	SHELL SIDE	TUBE SIDE
FLUID	Cold Water	Water Vapor		
VAPOR RATE, #/HR		400		
LIQUID RATE, GPM	88 GPM			
NON-CONDENSABLES, #/HR				
FLUID VAPORIZED OR CONDENSED		400		
GRAVITY (liq)/MOL. WT. (vapor)				
VISCOSITY @				
SPECIFIC HEAT @				
LATENT HEAT				
TEMPERATURE, IN	85°F	220°F		
" , OUT	94.6°F	130°F		
OPERATING PRESSURE,		Atmos.		
NUMBER OF PASSES	1	1		
VELOCITY, IN/OUT, ft/sec	5.64	51.6		
PRESSURE DROP				
HEAT DUTY, BTU/HR / M.T.D.,°F	424,000Btu/Hr/ 116°F			
FOULING FACTOR	0.002			

CONSTRUCTION

PRESSURE: DESIGN/TEST	75/113 Psig	75/113 Psig		
DESIGN TEMPERATURE	350°F	350°F		
MATERIAL OF CONSTRUCTION	Carbon Steel	304 Stainless		
DIMENSIONS	6" Dia.			
SPECIAL FEATURES		See Note(1)		
GASKETS	Garlock 900	Pfaudler-CLT		
CORROSION ALLOWANCE				
CODE REQUIREMENTS	ASME;TEMA"C"			
CONNECTIONS	150 Lb.Flgd.Nozz.In:2" Out	2" In: 3" Out: 1"		

NOTES:

(1) Upper Bonnet is channel type.
Tubes are 3/4" O.D. x 5"-0" long,
18 BWG, on 1" Tria. pitch.

THE PFAUDLER CO.
PROJECT ENGINEERING

HEAT EXCHANGER SPECIFICATIONS C-1

FOR U.S. Army Chemical Center

PROJECT G761-6006 DATE 4/28/61

BY WFS CHKD REV. 7/25/61
12/28/61

DWG NO SH 3 OF 18

IX-1	DEMINERALIZER	Permutit Model XP-15MB (Mixed Bed) Nuclear Purifier. 3.0 cu. ft. nuclear grade resin 1.0 part (vol.) Permutit QH (sulfonated styrene copolymer cation exchange resin). 1.75 part (vol.) Permutit S-1 (OH) (quartenary ammonium styrene base anion exchange resin).
IX-2	DEMINERALIZER	Same as IX-1, except 1.75 part (vol.) Permutit SK (OH) (quartenary ammonium anion exchange resin containing some pyridinium groups).

Manufacturer recommends operation in series, IX-2 followed by IX-1 to permit SK to pick up cobalt preferentially.

Samples of resin can be separated in saturated brine solution, cation resin sinks whereas anion resin floats. SK resin is expected to contain much more cobalt than S-1.

S-1	SEPARATOR	Pfaudler Order E361-1080 " Dwg. CE3-611080 18" O.D. x 35" O.A.H. 304 stainless, 11 Ga 5 psig design

Internal - Otto York #13865, one-piece wire mesh "Demister" 18" dia. x 18" thick. York very high efficiency, mesh. Top and bottom 1/4" round bar support grids.
Type 316 stainless.
York Drawing B-2447
Pfaudler Order P-78346-J

THE PFAUDLER CO.
PROJECT ENGINEERING
DEMINERALIZERS, IX-1 & -2 AND SEPARATOR, S-1

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 5/15/61
BY WFS CHKD. REV. 7/21/61
12/28/61
DWG. NO. SH. 4 OF 18

DESIG'N.	ITEM NO.	P-1	P-2	P-3 & P-4	
	ITEM	FEED PUMP (1)	RESIDUE PUMP (1)	DISTILLATE PUMP	
	TYPE	Positive Disp	Positive Disp	Centrifugal	
SERVICE	LIQUID	450-4000 PPM	30-60% Solids	Water	
	PUMPING TEMP,T	-70°F	215°F	130°F	
	SP. GR. @ T	1.0	1.2	1.0	
	VISCOSITY @ T	1 cp	5 cp	1 cp	
	VAP. PRESS. @ T		760 mm		
	GPM MAX. NORMAL MIN.	2.0 GPM 0.6 0.5	2 GPM	10 GPM	
PRESS.	SUCTION MIN.	10 PSIA	1 PSIG	1 PSIG	
	DISCHARGE NORM.	5 PSIG	5 PSIG	4 PSIG	
	T.D.H. required	30 Ft.	20 Ft.	16 Ft.	
	N.P.S.H. required	Low	Low	2 Ft.	
CONSTRUCTION	SEAL or S/B	Silicone "O" Ring	Same as P-1	"Canned"	
	BEARINGS			Carbon/Graphite	
	IMPELLER TYPE	Lobe	Do	Mfg. Std.	
	or PISTON MAT'L.	316 Stainless	Do	304 Stainless	
	SHAFT or ROD				
	LUBRICATION	Grease & Oil	Do	None R	
	CASING or CYL.	Copper Free Nickel Alloy	Do	304 Stainless	
	SUCTION	1-1/2"NPT	Do	1" NPT	
	DISCHARGE	1-1/2"NPT	Do	1" NPT	
DRIVER	TYPE	Dripproof	Do	Do	
	CURRENT	208 or 220V/3/60	Do	Do	
	R.P.M.	1800		3450	
	Drive	(2)	Fixed Speed V-Belt	-	
	H.P.	1/4 HP	1/4 HP	1/8 HP	
INSTALLED	MANUFACTURER	Waukesha (3)	Waukesha (3)	Dynapump	
	CAT. NO.	10 Do	10 Do	Model 670E	
	SERIAL NO.	A-78739	A-78740		
	DIMENSION DWG.	81359P	52957B		
	WEIGHT	250 Lbs	175 Lbs	25 Lbs	

NOTES:

(1) Self Priming
(2) Top shaft, Reeves Motodrive 93/280 RPM Frame No.111-1F-18 Assy.101
(3) Waukesha Foundry Co.

THE PFAUDLER CO.
PROJECT ENGINEERING

- PUMP SCHEDULE -

FOR U.S. Army Chemical Center
PROJECT G761-6006 DATE 6/15/61
BY WFS CHKD. REV. 7/21/61 12/28/61
DWG. NO. SH. 5 OF 18

		FI-1	FI-2A	FI-2	DRA-1A
	Item No.	FI-1	FI-2A	FI-2	DRA-1A
	Service	Fresh Feed Rotameter	Evap. Feed	Evap. Feed	Air Purge
	Type	Magnetic Indicator	Venturi	Bellows dP Indicator	Rotameter
	Pfaudler Order No.	P-78174-J	P-77924-J	P-80111-J	P-78174-J
	Manufacturer	S. & K. (1)	(2) Simplex	Barton	S. & K. (1)
	Cat. No.	Fig.1900F	Type TG	Model 257	Fig.1853
	Location	1/2 A-Z	1A-3	Panel	Panel
	Mfgs. Order	61-08-802M 60-S-158-M	J1-098 0/20711	62714 Rev.1	61-08-802M
	Dimension Dwg.	60-G-021-M			58-G-056-M-1
Specifications	**Size**	#3	1"	0-20" range	#2
	Connections	1" 150# Flg	1" welding	1/4" top, 1/2"	Bot. 1/8" NPT
	Materials of Construction	316 stainless & Viton	Stainless per NAVSHIPS 250-1500-1	Std.	Std. BP-5, Float
	Pressure Rating	150#		1000 psi	200 psig
	Scale	125 mm, GPH		0-10, sq.root	0-10
	Calibration	For water @ 70°F			
	Accessories		Seal pots	low dP switch	
Operating Conditions	**Fluid**	Water	Aqueous soln	Seal liquid	Air
	Mol. Wt. of Fluid	18	18		29
	Spec. Gravity	1.0	1.0		
	Viscosity	1.0 cs	approx 20 cp		
	Flow (Normal)		1 gpm		
	Flow Range		0-2 gpm		to 4.5 CFH
	Temperature	Ambient	105°F	200°F Max.	200°F Max.
	Upstream Pressure	below 5 psig	(3) 18" water		18 psig
	Pressure Drop	approx. 7.5" water	(4) 12" water		
		Instructions ML-19A.1-1		Instructions also Bull.257-1	Instructions 60-S-343-M Bull.18P 4/59

(1) Schutte & Koerting
(2) Simplex Valve & Meter Co.
(3) Operating head
(4) Max. differential (at 2 gpm)

THE PFAUDLER CO.
PROJECT ENGINEERING
Flow Indicators

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 6/15/61
BY WFS CHKD REV 8/21/61 12/28/61
DWG NO 5.270.5 SH 6 OF 18

	Item No.	FI-3	FI-4	SG-1	
	Service	Dist.Water	Demin.Water	Dist. water	
	Type	Rotameter	Rotameter	Sight Glass	
	Pfaudler Order No.	P-78174-J#4	P-83800-J	P-78714-J	
	Manufacturer	S & K (1)	F & P (2)	F & P (2)	
	Cat. No.	Fig. 18210	Model 10A2235A	205575 (10E1205)	
	Location	3/4 B-17		3/4B-12	
	Mfgs. Order	61-09-633-M			
	Dimension Dwg.	53-S-774-M-1 53-S-785-M			
Specifications	Size	5HCF			
	Connections	1" NPT	1/2" NPT	3/4" NPT	
	Materials of Construction	316 stainless	Bronze	316 stainless	
	Pressure Rating				
	Scale	direct reading 1-10 gpm	0-4 gpm		
	Calibration				
Operating Conditions	Accessories	51-J rotor		Hopper	
	Fluid	Water			
	Mol. Wt. of Fluid				
	Spec. Gravity	1.0			
	Viscosity	1.0 cp			
	Flow (Normal)				
	Flow Range	1-10 gpm			
	Temperature	70°F			
	Upstream Pressure				
	Pressure Drop				
		Instructions ML-18 RG.1 11/58	Horizontal mounting		

(1) Schutte & Koerting
(2) Fischer & Porter

THE PFAUDLER CO.
PROJECT ENGINEERING
Flow Indicators

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 12/28/61
BY WFS CHKD REV
DWG NO 5.270.5 SH 7 OF 18

	ITEM NO.	DRA-1	pHR-1	LC-1
	PFAUDLER ORDER NO.	P-78251-J	P-78801-J	P-78175-J
	SERVICE	Residue Density	pH Recorder	Residue Tank Level Controller
	CONTROL VALVE NO.	Recorder	-	LCV-1
SENSING ELEMENT	LOCATION	T-1	Line 1A-3	T-2
	TYPE	Air purge	Electrode probe	Ball float
	SIZE			3-1/2" dia.
	MATERIAL			Stainless
	CAPILLARY			-
	CONNECTION	1/4" NPT	1" NPT	-
	MFR. & MODEL NO.	-	Analytical Measurements	Moose Products
	ACCESSORIES	2 - S&K Rotameters on panel (1)	(3)	
TRANSMITTER	TYPE		Coaxial cable	Pneumatic
	MOUNTING			4" Flange
	DIST. HORIZ.& VERT.			
	MFR. & MODEL NO.			Moore Products Model 25
	ACCESSORIES			Input & output pressure gages
RECEIVER	LOCATION	Panel	Panel	
	TYPE	Mercury Manometer		
	CASE & MOUNTING	Rectangular	Rectangular	
	CONNECTION	1/4" NPT	-	
	CONTROL POINT	-	-	
	CHART RANGE	1.100-1.400	2 - 12	
	CHART PERIOD & DRIVE	7 day, electric	Strip, electric	
	MFR. & MODEL NO.	Taylor 76JD1115	Analytical Measurements	
	CONTROL ACTION			
	ACCESSORIES	High level electronic switch (2)		

(1) See DRA-1A on sheet 6

(2) Allen Bradley pressure switch, inside control panel, for low level.

(3) Standard probe is sealed in a 1" x 3" long stainless steel nipple for 100°C service.

THE PFAUDLER CO.
PROJECT ENGINEERING
REMOTE MOUNTED
CONTROLLERS, RECORDERS, INDICATORS

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 6/15/61 7/25/61
BY CHKD. REV. 12/29/61
DWG. NO. 5.270.3 SH. 8 OF 18

	ITEM NO.	LSA-1 & 1A	LSA-2 & 2A	LSA-3H & 3L
	PFAUDLER ORDER NO.	P-79291-J	P-79291-J	P-79291-J
	SERVICE	Distillate Tanks Level Controls	Demin. Tanks Level Controls	Feed Tank Level Alarms
	CONTROL VALVE NO.	LSV-1	LSV-2	None
SENSING ELEMENT	LOCATION	T-3A & 3B	T-4A & 4B	T-1
	TYPE	Single Probe	Single Probe	Double Probe
	SIZE	9" long	9" long	1-9" & 1-30"
	MATERIAL	316 SS	316 SS	316 SS
	CAPILLARY			
	CONNECTION	1" NPT (male)	1" NPT (male)	2" NPT (male)
	MFR. & MODEL NO.	Photoswitch	Photoswitch	Photoswitch
	Probe Holder (Model)	61LF1 (1000 M)	61LF1	61LJ2
	ACCESSORIES Probe	64CR1	64CR1	2 - 64CR1
TRANSMITTER	TYPE	#14 Wire	#14 Wire	#14 Wire
	MOUNTING			
	DIST. HORIZ.& VERT.			
	MFR. & MODEL NO.			
	ACCESSORIES			
RECEIVER	LOCATION	Panel	Panel	Panel
	TYPE 115V	Electronic	Electronic	Electronic
	CASE & MOUNTING	Chassis only	Chassis	Chassis
	CONNECTION Liquid Resistance CONTROL POINT	20,000 - 200,000 ohm/cc	200,000 - 2 MM	200 - 2,000
	CHART RANGE Power	6 Watts	6 Watts	6 Watts
	CHART PERIOD & DRIVE			
	MFR. & MODEL NO.	Photoswitch	Photoswitch	Photoswitch
	Type	13DJ3	13DJ3	13DJ3
	Model	1001C	1001C	1001C
	CONTROL ACTION On/Off	DPDT	DPDT	DPDT
	Electron Tube	1-125N7-GT	1-125N7-GT	1-125N7-GT
	ACCESSORIES Life	10,000 hr		

LSA-1 (LSA-2) energizes SV-1 (SV-2) on high level in T-3B (T-4B)
LSA-1A (LSA-2A) deenergizes SV-1 (SV-2) on high level in T-3A (T-4A)
LSA-3H and 3L sound alarm AL-1

THE PFAUDLER CO.
PROJECT ENGINEERING
REMOTE MOUNTED
CONTROLLERS, RECORDERS, INDICATORS

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 8/23/61
REV. 12/29/61
BY WFS CHKD.
DWG. NO 5.270.3 SH. 9 OF 18

ITEM NO.	LCV-1	L5V-1&2	SSV-1	
PFAUDLER ORDER NO.	P-78251-J	P-78251-J	P-78084-J	
MANUFACTURER	Taylor	Taylor	Foxboro	
MFR'S TPYE OR MODEL NO.	700VB4740	310WC4220	No.34169	
SERVICE	Fresh Feed	Water Diver	Steam	
CONTROLLER ITEM NO.	LC-1	LS-1 & 2	STA-3	
Serial No.	14982			
Mfg. Order No.	0802593			
SPECIFICATIONS — TYPE	Saunders Pat.	3-Way		
MOTOR	Diaphragm	Diaphragm	Diaphragm	
MOTIVE POWER	18 psi air	18 psi air	18 psi air	
ACTION	air-to-close	-	air-to-open	
CONTROL		Diversion	On/Off	
SIZE & CONNECTIONS	1/2" screwed	3/4" screwed	1" screwed	
MATERIAL-BODY	316 stainless	316 stainless	Cast bronze	
MATERIAL-TRIM			Nickel alloy	
MATERIAL-PACKING				
PRESSURE RATING	150 lb.	150 lb.	100 psig	
ACCESSORIES				
OPERATING CONDITIONS — FLUID	Water	Water	Steam	
MOL. WT. OF FLUID				
SPEC. GRAV.	1.0	1.0		
VISCOSITY	1.0 cp	1.0		
FLOW (normal)			500#/hr	
FLOW RANGE	0-2 gpm	0-1 gpm		
TEMPERATURE	Ambient	130°F Max.	325°F	
UPSTREAM PRESSURE				
PRESSURE DROP	2 psi	12" water max.	10 psi	

THE PFAUDLER CO.
PROJECT ENGINEERING

MOTOR CONTROL VALVES

FOR U. S. Army Chemical Center

PROJECT G761-6006 DATE 6/15/61

BY WFS CHKD. REV. 7/25/61 1/2/62

DWG. NO. 5.350.2 SH. 10 OF 18

TEMPERATURE INSTRUMENTS (FILLED SYSTEM)

SPECIFICATION SHEET

THE PFAUDLER CO.
PROJECT ENGINEERING

FOR Army Chemical Cente
PROJECT G761-6006 8/21/61
BY WFS CHKD REV. 1/2/62
DWG NO. SH 11 OF 18

TI-1 & 2 The Foxboro Co.
Pfaudler P.O. P-79203-J

GENERAL

1 DESCRIPTION RECORDER ☐ INDICATOR ☒ BLIND ☐ CONTROLLER ☐ TRANSMITTER ☐
2 CASE RECTANGULAR ☐ CIRCULAR ☒ 5" OTHER ____
3 CASE COLOR BLACK ☒ OTHER ____
4 MOUNTING FLUSH ☒ SURFACE ☐ YOKE ☐
5 NO. PTS.-- RECORDING ____ INDICATING ____
6 CHART SIZE 12" CIRC. ☐ OTHER ____
7 CHART RANGE ____ NUMBER ____
8 SCALE RANGE 100-270 °F TYPE ____
9 CHART DRIVE SPRING ☐ ELECTRIC ☐ PNEUM. ☐
10 CHART SPEED ____ WIND ____
11 V ____ C ____ EX.PRF. ☐ AIR PRESS. ____
12 OTHER ____

TRANSMITTER

13 TYPE PNEUMATIC ☐ ELECTRIC ☐
14 OUTPUT 3-15 PSI ☐ OTHER ____
15 RECEIVERS ON SHEET NO. ____

CONTROL

16 TYPE PNEUMATIC ☐ ELECTRIC ☐ OTHER ____
17 PROP. ____ % AUTO-RESET ☐ RATE-ACTION ☐ ON-OFF ☐ OTHER ____
18 OUTPUT 3-15 PSI ☐ OTHER ____
19 ON MEASUREMENT INCREASE OUTPUT: INCREASES ☐ DECREASES ☐
20 ELECTRIC SWITCH TYPE - ON MEASUREMENT INCREASE CONTACTS OPEN ☐ CLOSE ☐
21 CONTACT RATING AMPS. ____ VOLTS ____

AUTO-MANUAL SWITCH

22 NO. POSITIONS ____ EXTERNAL ☐ INTERNAL ☐ INTEGRAL ☐

SETPOINT ADJUSTMENTS

23 MANUAL INTERNAL ☐ EXTERNAL ☐
24 AUTO-SET PNEUMATIC ☐ ELECTRIC ☐
25 BAND FIXED ☐ ADJUSTABLE ☐
26 OTHER ____

NOTE:

THERMAL ELEMENT

27 CLASS IA ☐ IIA ☒ IIIA ☐ VA ☐ IB ☐ IIB ☐ IIIB ☐ VB ☐ IIC ☐ IID ☐
28 RANGE ____ OVERRANGE PROTECTION

BULB 3/8" Dia.

29 PLAIN ☐ UNION CONN. ☒ SANITARY ☐
30 EXTENSION RIGID ☒ ANGLE ☐ BENDABLE ☐ OTHER ____
31 INSERTION LENGTH, INCHES 12"
32 MATERIAL 316SS ☒ OTHER ____
33 BULB IS 3 FEET ABOVE INSTRUMENT CASE TI-2
3 FEET BELOW INSTRUMENT CASE TI-1

BULB CONNECTIONS

34 FLANGE ☐ THREADED ☒ CLAMP ☐ OTHER ____
35 BUSHING 3/4" ☒ 1" ☐
WELL 3/4" ☐ 1" ☒ EXT. ☐
36 MATERIAL 316SS ☒ OTHER ____
37 SANITARY 3A ☐ OTHER ____

CAPILLARY TUBING

38 LENGTH 15 Ft
39 TYPE ARMORED ☒ PLAIN ☐
40 MATERIAL CAPILLARY: STNL. STL. ☐ COPPER ☐ ARMOR: STNL. STEEL ☐ BRONZE ☐
OTHER ____ PLASTIC OVER BRO. ☐ LEAD ☐ OTHER ____
41 CONNECTION AT CASE BACK ☐ BOTTOM ☐

ACCESSORIES

42 FILTER & REGULATOR ____
43 AIR SUPPLY GAGE ____
44 LOCAL INDICATOR ____
45 CHARTS & INKSET ____
46 MOUNTING YOKE ____
47 PORTABLE CASE FEATURES ____
48 MOUNTING ACCESSORIES FOR WET & DRY BULBS ____
49 ALARM SWITCH ____
HERMETICALLY SEALED ☐ E.P. ☐ G.P. ☐

INDICATING BIMETAL THERMOMETERS

SPECIFICATION SHEET

THE PFAUDLER CO.
PROJECT ENGINEERING

FOR Army Chemical Center
PROJECT G761-6006 8/21/61
BY WFS CHKD. REV 1/2/62
DWG. NO. SH. 12 OF 18

TI-3 American-Standard Rochester Instruments
Pfaudler P.O. P-79204-J
Mfg. # R.I. 47555

GENERAL

1 BULB TYPE THREADED ☒ PLAIN ☐ UNION ☐
OTHER
2 CASE MATERIAL MFGR STD ☒ OTHER
3 DIAL SIZE 5" COLOR stainless
4 FORM STRAIGHT ☐ ANGLE ☐
FIXED ☒ ADJUSTABLE ☐
5 BULB OR UNION THREAD SIZE 1/2" ☒ 3/4" ☐
6 MFGR MODEL NO. 1850

Stem at 3 o'clock

WELL

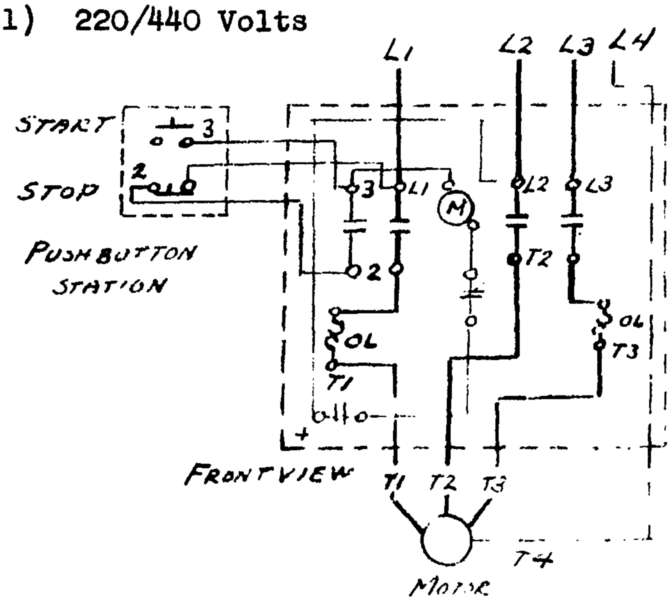
7 MATERIAL 304SS ☒ 316SS ☐
OTHER
8 CONSTRUCTION BUILT-UP ☐ DRILLED BAR STOCK
OTHER
9 THREAD SIZE NPT MALE 1" ☐ OTHER 3/4"
FEMALE 1/2" ☐ OTHER
10 LAG EXTENSION "T" NONE SHOWN BELOW ☐
3"
11 MFGR. MODEL NO. Type 1

REV	QUAN	TAG NO.	RANGE °F	OPER TEMP.	"U" DIMEN.	"T" DIMEN.	SERVICE	NOTES
	1	TI-3	0-220	100	4"		Distillate	

NOTES: "U" = Stem length

	STA-1	STA-2	STA-3	STA-4	STA-5
STARTER FOR ITEM	P-1	P-2	P-3	P-4	E-1
TYPE STARTER	Magnetic				
NEMA TYPE	Open	Same as P-1			#4 (T.E.)
ELECTRIC CURRENT	220/3/60 (1)				
H.P. / R.P.M.	1/4/	1/4/1200	/3450	/3450	3/1800
MFG. of Starter	G.E.				
FORM	CR1068003	Same as P-1			
SIZE	0				
Motor/Heaters	1.16/1.18	1.16/1.18	0.9/0.94	0.9/0.94	3.5/3.72
HOLDING COIL (SOLENOID)	110 Volts	Same as P-1			
FURNISHED BY	Pfaudler				
STARTER FOR ITEM					
TYPE					
NEMA TYPE					
ELECTRIC CURRENT					
H.P.					
MFG.					
FORM					
SIZE					
TYPE					
HOLDING COIL (SOLENOID)					
FURNISHED BY					

(1) 220/440 Volts



THE PFAUDLER CO.
PROJECT ENGINEERING
STARTER SPECIFICATIONS & Motors

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 1/2/62
BY WFS CHKD REV
DWG NO SH 13 OF 18

Item No.	Item	Mfg.	Cat. No.
PL-1 thru 18	Panel Lights	GE,	CR2940UE212A2
6	Amber Caps	GE	CR2940U200K
3	Red Caps		200H
9	Green Caps		200J
	Three position Selector Switches		
SS-1 & 2	Cam #2 Spot	GE,	CR2940 UB 202B
SS-3 & 4	Double contact block, cam #6		UB 203F
3	Black start buttons	GE,	CR2940 UA 202B
4	Red stop "		202C
PSW-1	Pressure Switch	AB	836CV11-BJC
FB-1 to 6	Fuse Blocks		
CR-1 to 22	20 Relays	SD	219ABAP
CR-13 & 19	2 Relays (latch)	SD	255XCXP
CR-23	1 Relay (time delay)	AB	849ZØD32
FL-1	Flashing Relay		Amperite
CT-1	220/110 volt transformer	GE	9T51Y 6233
AL-1	Alarm, horn		
AL-2	" , buzzer		
AL-3	" , bell		

THE PFAUDLER CO.
PROJECT ENGINEERING

MISCELLANEOUS PANEL ITEMS

FOR U.S. Army Chemical Center

PROJECT G761-1200 DATE 8/8/61

BY WFS CHKD. REV. 1/2/62

DWG. NO. SH. 14 OF 18

1 -	Seal Pots	Foxboro	P #20230
1 -	Air Filter	"	
2 -	Pressure Regulators		
SV-1 to 3	Solenoid Valves	Gen Controls	
	Dehydrafilter	Hankinson	

THE PFAUDLER CO.
PROJECT ENGINEERING
MISCELLANEOUS NON-PANEL ITEMS

FOR U. S. Army Chemical Center
PROJECT G761-1200 DATE 8/8/61
BY WFS CHKD. REV.
DWG. NO. SH. 15 OF 18

VALVE TAG NUMBER	1V	2V	3V	4V	1V
LINE SERVICE	A, B & C	A	B & C	A & B	1B-16
MANUFACTURER	Worcester	Continental	Continental	Cooper Alloy	Jamesbury
MFG'S. NUMBER	Type 400	Fig. 37	Fig. 36	Fig. 2001	
VALVE - MATERIAL	316 stainless	316 stainless	316 stainless	316 stainless	316 stainless
VALVE - PACKING	Teflon	Teflon	Teflon		
VALVE - TYPE	Ball	3-way plug	3-way plug	Swing Check	Ball
Pfaudler P.O.	P-79663-J	P-78309-J	P-78309-J		P-81663-J
	Screwed	150# Flg	Scwd	Dcwd	
SIZE & CONNECTION	1/2",3/4"1"	1"	3/4"	1/2"	1" Scwd
NUMBER FURNISHED	6 6 4	1	3	1	1

TAG NUMBER					
LINE SERVICE	15-61	1V-52			
MANUFACTURER	Jamesbury	Jamesbury			
MFG'S. NUMBER	D22-TT	D88-TT			
VALVE - MATERIAL	Steel	PVC			
VALVE - PACKING					
VALVE - TYPE	Ball	Ball			
SUPPLIER	Haverstick	Haverstick			
PFAUDLER ORDER	P-80013-J	P-81812-J			
SIZE & CONNECTION	1" Scwd	1" Scwd			
NUMBER FURNISHED	1	1			

THE PFAUDLER CO.
PROJECT ENGINEERING

MANUAL VALVES

FOR U. S. Army Chemical Center

PROJECT G761-1200 DATE 8/8/61

BY WFS CHKD REV 1/2/62

DWG NO SH 16 OF 18

VALVE TAG NUMBER					
LINE SERVICE					
MANUFACTURER					
MFG'S. NUMBER					
VALVE - MATERIAL					
VALVE - PACKING					
VALVE - TYPE					
SIZE & CONNECTION					
NUMBER FURNISHED					

	Swivel	Relief Valve	Line Strainer		Vapor Duct
TAG NUMBER	SW-1	RV-1	S-2		D-1
LINE SERVICE	3/4 A-7	1/2 A-9	3/4 A-1		S-1 to C-1
MANUFACTURER	Chiksan	Aveco	Cooper Alloy		Pfaudler
MFG'S. NUMBER	Style 20	Series 1-5	Fig. 241		E361-1692
MATERIAL	316 S/S	304 S/S	Stainless		304 S/S
- PACKING	Hycar		Bolted cover		Mill Finish
- TYPE	180 deg.	Liquid Relief	"Y"		Straight 3"dia.x21"
SUPPLIER	R.H.Perry Co.	J.V. Tripoli	Screen = 0.045"		-
PFAUDLER ORDER	P-78800-J	P-79205-J	Haverstick P-79684-J		-
SIZE & CONNECTION	3/4" Scwd	1/2" Scwd	3/4" Scwd		3" Flgd
NUMBER FURNISHED	1	1	1		1

THE PFAUDLER CO.
PROJECT ENGINEERING
Special Pipe Fittings

FOR U. S. Army Chemical Co.
PROJECT G761-6006 DATE 6/13/62
BY WFS CHKD REV 1/2/62
DWG NO SH 17 OF 18

PROCESS LINES

All Manual Valves	- Ball type, screwed connections, type 316 stainless with Teflon sleeve.
All Check Valves	- Swing type, screwed connections, type 304 stainless.
Fittings	- Either 150 lb. screwed, type 304 stainless or Swagelock type tube fittings (316 stainless). Use tees in place of elbows at low points with run of tee horizontal (stem vertical) and with a nipple and cap in place of plugs in the unused opening.
Flanges	- 150 lb. MSS, type 304 stainless
Unions	- 150 lb. type 304 stainless, ground joint, steel to steel.
Reducers	- Bushings & Couplings
Gaskets	- Ring type, Teflon envelope
Pipe	- Type 304 stainless, schedule 40
Tubing	- 18 ga. type 304 stainless steel

Steam and Water Lines

Iron and Steel

Vent Lines

Rigid PVC

THE PFAUDLER CO.
PROJECT ENGINEERING
PIPING SPECIFICATIONS

FOR U. S. Army Chemical Co.
PROJECT G761-6006 DATE 6/13/61
BY CHKD. REV. 1/3/62
DWG. NO. SH. 18 OF 18

	Wt. Full (Supports)	Wt. Empty (Rigging)			E H.P.	S #/hr	C.W. gpm	Air CFM	
10	1800	1800		Structural Frame					
	1000	865	E-1	Evaporator	1	400			
	750	150	T-1	Feed Tank, 65 gal					
	750	175	T-2	Residue Tank, 50 gal		20			
	3000	360	T-3	Distillate Rec., 300 gal					
	3000	360	T-3A	" " " "					
	3000	360	T-4	Demin. Rec., 300 gal					
	3000	360	T-4A	" " " "					
	600	400	C-1	Condenser			88		
11	500	200	S-1	Separator					
1	350	270	IX-1	Ion Exchanger					
1	350	270	IX-2	" "					
2	300	300	P-1	Feed Pump	1/4				
2	200	200	P-2	Concentrate Pump	1/4				
3	25	23	P-3	Distillate Pump	1/8				
3	25	23	P-4	Demin. Pump	1/8				
4	5	5	FI-2	Venturi					
5	20	15	SSV-1	Steam Valve					
6	25	20	FI-3	Rotameter					
6	45	40	FI-2	Venturi & Indicator					
7	25	20	LC-1	Level Controller					
8	40	30	LSV-1 & 2	(2) 3-way Valves					
8	20	15	LSV-1	Feed Control Valve					
8	40	40	DRA-1	Density Recorder					
9	15	10	2V	(1) 3-way Plug Valve					
9	20	15	3V	(3) 3-way " "					
12	5	5	SG-1	Sight Glass					
13	5	5	SW-1	Swivel					
21	400	400	PN-1	Control Panel	1/8			2	
	18930	6351							

E - Electricity, HP
S - Steam, #/hr @ 75 psig
C.W. - Cold Water, GPM

THE PFAUDLER CO.
PROJECT ENGINEERING
EQUIPMENT WEIGHTS & UTILITY DEMANDS

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 9/19/61
BY WFS CHKD. REV. 1/4/62
DWG. NO. SH. 1 OF 2

15	(75)	(50)		Pipe Fittings					
15	3	3		1 - 1/2" Check Valve					
16	(35)	(25)		Tube Fittings					
17	4	4		2 - Dial Therm.					
18	2	2	TI-3	1 - Therm					
19	1	1	RV-1	1 - 1/2" Relief Valve					
20	2	2		Dehydrafilter					
14	15	15	pHR-1	pH Recorder					
22	25	25		(5) Level Switch Probes					
23	25	25		(13) Ball Valves					
24	(75)	(50)		Pipe Fittings					
25	3	3		3 - Solenoid Valves					
26	3	3		3/4" Pipeline Strainer				#/ft	
27	28	28		20 ft 1" sch 40 Pipe				1.40	
27	18	18		20 ft 3/4"sch 40 Pipe				0.857	
27	7	7		10 ft 1/2" sch 40 Pipe				0.67	
27	50	50		100 ft Tubing				(0.5)	
28	20	20		Electrical Equip.					
29	5	5		Rubber & Plastic Fittings					
29	5	5		Stainless					
30	20	20		Stainless Fittings					
31	15	15		FI-2					
32	100	100		Steel Pipe & Fittings					
	921	861							
	18930	6351							
	19851	7212							

THE PFAUDLER CO.
PROJECT ENGINEERING
EQUIPMENT WEIGHTS

FOR U. S. Army Chemical Center
PROJECT G761-6006 DATE 9/19/61
BY WFS CHKD. REV. 1/4/62
DWG. NO. SH. 2 OF 2